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ORIGINAL ARTICLES.

I.—British Liassic Gasteropoda.

By E. Wilson, F.G.S.; Curator of the Bristol Museum.

(PLATE V.)

Introduction.

THE Gasteropoda, next to the Lamellibranchiate Mollusca, are the most varied class of organisms found in the Lias. The general elegance of their forms, and the frequent beauty of their ornamentation, make these fossils extremely attractive objects; whilst their limited vertical range gives them a by no means inconsiderable stratigraphical importance. Notwithstanding these inducements to their study, the Gasteropoda of the Lias have not received, in this country, anything like the amount of attention which has been given to the other leading classes of organisms derived from that formation. On the Continent, on the other hand, considerable progress had been made in the investigation of this interesting group of fossil mollusca more than thirty years ago. The elaborate Memoirs of Münster (in Goldfuss's "Petrefacta Germaniæ"), D'Orbigny (in the "Paléontologie Française"), Deslongchamps the elder, Dunker and Terquem, Chapuis and Dewalque, furnish the basis of our knowledge of the Gasteropoda of the Lias, whilst in later years Messrs. Eudes Deslongchamps, Stoliczka and Piette, Jules Martin and Dumortier, have each and all contributed a large amount of very valuable information in this department of Palæontology. The above difference, to our disadvantage, is perhaps to be explained, in part at any rate, by the more localized distribution of Gasteropodous Mollusca in the English Lias, by their prevailing small size, and the comparative rarity of the more conspicuous forms, such as the Pleurotomariæ, and finally, by their generally more highly mineralized condition, and the consequent greater difficulty there is, in this country, in extracting these fossils in anything like perfect condition.[1] During recent years, however, an increasing amount of attention has been given to the palæontology of the English Lias. In this work a number of earnest students are now actively engaged, chiefly in the Midlands, a district which had previously been greatly neglected, and one of

[1] In the Lias of Luxembourg and Hettange, several Gasteropods have been found, which are not only perfect in form, but even retain the original colours and markings of the shells. (See Terquem, "Paléontologie de Hettange," Mem. Soc. Geol. France, 2nd ser. vol. v. pp. 219–343, pl. xii.–xxvi.)

the results of their labours has been to materially add to our knowledge of the Gasteropoda of the Lias formation.

The following summarized account will serve to illustrate the progress which has been made in this branch of Palæontology in recent times. In the Catalogue of British Fossils (2nd edition), published by the late John Morris in the year 1854, only six species of Gasteropoda are quoted from the Lias formation, viz. *Pleurotomaria Anglica*, *Pl. compressa*, *Pl. expansa*, *Trochus imbricatus*, *Turbo undulatus*, and *Dentalium giganteum*. In 1872, twenty-three species had been obtained from the Lias of Yorkshire, but in 1876 this number was, through the labours of Messrs. Tate and Blake, increased to 89 (see "Yorkshire Lias," p. 331). Mr. E C. H. Day in 1863 obtained 40 species of Gasteropoda from the Middle Lias of Dorsetshire, many of which were new to this country, and appear to be confined to that district (Q.J.G.S. vol. xix. p. 278, and vol. xxxiii. p. 167). One of the most indefatigable students of the palæontology of the Lias at this period was the late C. Moore, who chiefly worked in the Somersetshire and S. Wales areas. The fruits of the labours of that very capable geologist are to be seen in the splendid "Moore Collection" of Lias fossils in the Bath Museum. This collection, which is, I believe, richer in Lias Gasteropoda than any other in England, contains 180 named British species, including no less than 90 type forms, many of which are unique both in their interest and rarity.[1] In 1871 Prof. Ralph Tate, in his "Census of the Marine Invertebrate Fauna of the Lias," enumerated 269 species representing 32 genera of British, as compared with 650 species representing 43 genera of Continental Liassic Gasteropoda (Geol. Mag. Vol. VIII. 1871, p. 4). Mr. R. Etheridge, F.R.S., in his Presidential Address to the Geological Society in 1882, "On the Analysis and Distribution of the British Jurassic Fossils," quotes 388 species, which are classed by him under 51 genera, from the Lias of Great Britain. Of this large number only six[2] species are stated to pass up into the Inferior Oolite, viz. *Actæonina pulla*, *Amberleya capitanea*, *Cerithium papillosum*, *Natica adducta*, *Onustus pyramidatus*, and *Pleurotomaria princeps*, one of which (*A. capitanea*) survived into the Forest Marble (Q.J.G.S. vol. xxxviii. p. 165). In reference to the foregoing account I would observe, without in any way questioning the general accuracy of the figures given by my esteemed friend Mr. Etheridge, or the validity of the conclusions founded thereon, that the number both of the species and of the genera appear rather too high for what they respectively represent. It was admitted, for instance, that the 136 Middle Lias names represented only 118 true species, and this, apart from any similar deduction for duplicated nomenclature in the

[1] See Quart. Journ. Geol. Soc. vol. xxiii. p. 449, pl. 14–16; Proc. Somerset Arch. and Nat. Hist. Soc. vol. xiii. p. 119, pl. 4–6. It is unfortunate that these types should have been so indifferently delineated. Moore's sketchy figures give but a poor idea of the beauty of these fossils, and, in several instances, are so inaccurate as to be positively misleading as to their form. Students of this group should therefore beware of too readily trusting to identifications founded solely on comparisons of their specimens with these figures.

[2] This number is certainly capable of increase.

other two divisions of the Lias, would reduce his gross total to 370. Then again we find some of the genera repeated under different names: '*Amberleya*,' '*Eucyclus*,' and '*Tectaria*,' for example, are cited as three instead of as one only, and similarly the synonymous *Actæonina* and *Orthostoma* are apparently counted as two.

I have recently drawn up lists of the British Liassic Gasteropoda which, exclusive of those now described, comprise 425 species, distributed provisionally under 51 genera. In these lists care has been taken to avoid the reduplication of names, but it is probable that a small number of the species have been counted twice under different synonyms. These last, however, will, I believe, be more than balanced by the various new forms now awaiting description. The number of genera on the other hand is almost certainly too great. The 425 species are very unequally distributed among the genera. The dominant Liassic genera are *Trochus*, *Turbo*, *Cerithium*, and *Pleurotomaria*. Taking with the last the sub-group *Cryptænia*, each of these genera would comprise about 50 species, or together nearly a moiety of the whole number. Next comes *Chemnitzia* with some 30 species, and then *Amberleya* (=*Eucyclus*) *ctæonina* (= *Orthostoma*), *Turritella*, and *Patella*, with from 10 to 16 each. The following genera are represented by an average of 6 species each: *Actæon* (= *Tornatella*), *Alaria*, *Dentalium*, *Discohelix*, *Eulima* (= *Niso*), *Littorina*, *Natica*, *Neritopsis*, *Phasianella*, *Pitonillus* (= *Rotella*), *Solarium*, *Straparolus* and *Trochotoma*; whereas *Cylindrites*, *Cryptaulax*, *Delphinula?*, *Euomphalus?*, *Kilvertia* (=*Exelissa*), *Monodonta*, *Nerita*, *Neritina*, *Oustus*, *Purpurina*, *Rimula* and *Rissoa* are represented by 1 to 3 species each only. The remaining genera, which are mostly founded on extremely few forms, and in some cases on single and imperfect or on minute and immature specimens, cannot be considered to be satisfactorily established at present. These are *Chiton*, *Conus*, *Fusus*, *Nerinæa*, *Pterocera*, and *Pyrula*, one if not both of Moore's genera *Pleuratella* and *Pterocheilos*, and the following terrestrial and freshwater types:—*Ampullaria*, *Helix*, *Hydrobia*, *Melania*, *Planorbis*, *Proserpina*, *Valvata*, and *Vertigo*. Some of the foregoing are pretty sure to break down as Liassic genera under closer scrutiny and the acquisition of more satisfactory material. Indeed, it is very questionable whether any one of the first six of the above genera can be maintained; and, before accepting any *land* or *freshwater* form, as coming from a formation so essentially marine as the Lias, we must require in each case the most clear and convincing evidence. The net result of a future revision will probably be to reduce the number of generic types given above, whereas the species are probably capable of an appreciable and immediate increase.

The enumeration of 425 species of British Liassic Gasteropoda in 1886 as compared with the trivial number of six only in 1854, is a striking illustration of the progress which has been made in Palæontology in this country during the last thirty years.

Without further preface, I proceed to the main object of the present communication, which is to describe thirteen species of Gasteropoda. These are mostly new to science, and all are new to the British Lias.

For a full moiety of the material on which the following species are founded I am indebted to Mr. W. D. Crick, of Northampton, who has very generously placed a number of interesting specimens at my disposal for the above purpose, and has also furnished me with much valuable information as to their precise geological position. I am under a considerable obligation to the Rev. H. H. Winwood, M.A., F.G.S., for the facilities he has kindly given me for examining the specimens in the Bath Museum, to Mr. H. E. Quilter, of Leicester, for assistance with specimens from that county, and to Mr. T. Beesley, F.C.S., of Banbury, and Mr. B. Thompson, F.G.S., of Northampton, for useful information on the general subject.

Note.—In the following descriptions, the "sutural angle" is the greater angle which the suture makes with the side of the spire; and the "length of the last whorl" is measured axially, and posteriorly when practicable, from the anterior extremity of the aperture to the last preceding suture.

Description of New Species.

Trochus Dalbiensis, spec. nov. Pl. V. Figs. 1, 1*a*, 1*b*, 1*c*.

Description.—Shell conical, as broad as high; imperforate; spiral angle concave, apex acute; whorls 7, slightly concave, separated by deep sutures, last whorl very large relatively, squarely angulated at the periphery. The ornamentation of this very pretty little shell is as follows:—Numerous slender radial costæ commence close to the posterior suture in a row of fine granulations, apparently formed at the junctions of the costæ with a fine encircling thread, and are continued forwards rather obliquely across two rows of larger rounded tubercles, similarly occurring at the decussations of the costæ with fine encircling threads; these two granulated lines occupy the anterior third of the whorls, and the anterior one of the two, which is the most prominent, gives a distinct angulation thereto; from each of the tubercles of this anterior row two fine threads pass downwards obliquely across the deep sutural groove, and terminate in a finely-granulated encircling thread close to the anterior suture. Base of shell almost flat, very slightly convex, with 12 or more very finely-crenulated concentric threads, which are closer together towards the centre and circumference, and wider apart in the intermediate area. Aperture trapezoidal, transverse and oblique. Outer lip boldly arched, inner lip almost straight and effuse over the columellar border.

Dimensions.—Length, 8 millimètres; diameter, 8 mm.; length of last whorl, 5 mm.; spiral angle, 70°; sutural angle, 128°.

Affinities.—This species is somewhat closely related to *Tr. Thetis*, Mün. (Goldfuss, Petr. Germ. pl. 179, figs. 10*a*, *b*: and Plate V. Figs. 2*a*, *b*, *c*). It differs therefrom by its finer ornamentation, the *double* row of anterior tubercles, the fine granules over the suture, and the more numerous concentric striæ on the base, also by its greater spiral angle, larger number of whorls, and more acuminate apex. Judging by the specimens of this latter species found at Dalby associated with the foregoing form, Münster's figure (*loc. cit.*) errs in showing unduly straight costæ, want of tubercles on the keel,

a roundly-furrowed instead of a sharply-ribbed base, and an apparent and large umbilicus.

Note.—Trochus Thetis seems to be a difficult form to delineate. It has several times been re-figured, but never drawn with perfect accuracy. The figures I give (Pl. V. Figs. 2, 2*a*, *b*, *c*) are an advance on most of the previous figures, but the appearance of an umbilicus is fallacious.

Geological Position and Locality. — Lower Lias, zone of *Am. oxynotus*, Railway-tunnel, Old Dalby, Leicestershire.

TROCHUS CRICKI, spec. nov. Pl. V. Figs. 3, 3*a*, 3*b*.

Description.—Shell conical, imperforate; spiral angle regular, very slightly concave, apex acute; whorls 5-6. quite flat; sutures linear, only slightly inclined; last whorl obtusely angulated at the circumference; base almost flat, very slightly convex; columella prominent, massive and vertical; outer lip imperfect, but the aperture when complete appears to have been rhomboidal and only a little wider than high. The whorls are covered with close-set spirals of small rounded tubercles, the spiral lines and the individual tubercles being respectively closer together than their interspaces; on the penultimate whorl there are 5-6 spirals; the tubercles of the most anterior row of these are a little the largest, and give a slight tabulation to the whorls, the row next behind are nearly equally large, then there is a very fine row, and behind these two rather coarser rows; on the last whorl 4 rows of coarser tubercles occupy the angular border, posterior to which are 4 rows of finer tubercles; on the base immediately within the 4 coarse granular lines are 3 finer lines, of which the outer one only is granular; the rest of the base is smooth.

Dimensions.—Length, 5 millimètres; diameter, 4 mm.; length of last whorl, 3·25 mm.; spiral angle, 65°; sutural angle, 130°.

Affinities.—This small shell appears to have rather close affinities with certain small Oolitic Trochi having granulated spires and smooth bases, such as *Tr. monilitectus*, Phil., and its allies *Tr. Scarburgensis*, Hudl., and *Tr. strigosus*, Lyc., figured and described by Mr. W. H. Hudleston, M.A., F.R.S., in his "Palæontology of the Yorkshire Oolites" (GEOL. MAG. Dec. III. Vol. II. 1885, p. 121, *et seq.*). It does not, however, appear to be absolutely identical with any of these.

Obs.—I name this fossil after Mr. W. D. Crick, of Northampton, whose valuable work on the palæontology of the Lias of that district has already been acknowledged.

Geological Position and Locality.—Middle Lias, zone of *Am. margaritatus*, Daventry, Northamptonshire.

TROCHUS SAGENATUS, spec. nov. Pl. V. Figs. 4, 4*a*.

Description. — Shell conical, turrited, imperforate; spiral angle regular; whorls 8 probably (the apex being lost in my sole specimen), a little concave and slightly imbricating. Each whorl bears 3 equidistant encircling raised lines one a little in advance of the posterior suture, the second a little in front of the middle of the whorl, and the third forming a slight keel directly overhanging the

deeply cut but very narrow suture; these are crossed by numerous slender, slightly oblique, radial costæ, forming with the spiral lines a neat meshwork, having little nodules at the decussations; the radial costæ are more slender and more closely set on the last whorl. Base almost flat, bearing numerous fine encircling threads with nearly equal interspaces; the radial costæ are continued over the angular border of the last whorl, to which they give a fine crenation, and then rapidly die away. Aperture depressed, lunate and oblique, outer lip somewhat thickened, columella inconspicuous.

Dimensions.—Length (restored), 6·75 millimètres; diameter, 4 mm.; spiral angle, 35°; sutural angle, 110°.

Affinities.—This form appears to be related to *Trochus Holwellensis*, Moore, a fossil derived from the Liassic deposit contained in fissures of the Mountain Limestone near Frome (Q.J.G.S. vol. xxiii. p. 554, pl. 17, figs. 1, 2). The types of this species should be in the Bath Museum, but they are unfortunately missing. Comparison of our specimen with Moore's figure, however, shows that whilst the two fossils agree in general form and ornamentation, *Tr. Holwellensis* had a more elongated spire, the whorls of which, instead of imbricating each other, were separated by wide and deep sutures, and bore fewer and coarser radial costæ, making prominent "bosses" on the margin of the last whorl. Moore's type appears also to have had a small umbilicus. These points of difference seem quite sufficient to distinguish the two forms specifically.

Geological Position and Locality.—Upper Lias (transition-bed to Middle Lias), L. and N. W. Railway, Watford, Northamptonshire.

Trochus Northamptonensis, spec. nov. Pl. V. Figs. 5, 5*a*.

Description.—Shell conical, imperforate; apex acute; spiral angle, regular or slightly convex; whorls 7, concave; a prominent and acute crenulated ridge or carina encircles the anterior portion of the whorls, and a similar but much less prominent ridge encircles the whorls close to the posterior suture; between these there is a concave area occupying two-thirds of the width of the whorl; from the anterior carina the surface of the whorl falls vertically to the anterior suture, this portion occupying about a third of its width; the last whorl is tricarinated, having two anterior crenulated carinæ, the posterior of which is the more prominent; broad undulating costæ run somewhat obliquely from the spinose points of the posterior to those of the anterior carina, beyond which they are continued vertically to the anterior suture, and on the last whorl, after connecting the spinose points of the two anterior carinæ, are continued in more or less prominent serpentine ridges from the circumference to the centre of the base. A few faint encircling lines are discernible in the concave portions of the whorls. The whole shell is covered with fine close-set radiating flexuous lines, which pass over the costæ and their interspaces, the carinæ and the base. The base is only slightly convex, but prominent in the centre, and marked with numerous concentric lines, which are either equally distinct and

spaced from circumference to centre, or are much more distinct and more widely spaced towards the circumference, in addition to the radial serpentine lines and ridges above mentioned. Aperture transverse, outer lip thin, with an irregular outline; inner lip concave, with a broad expansion over the massive, axial and somewhat obliquely produced columella.

Dimensions.—Height, 10·75 millimètres; diameter, 9 mm.; length of the last whorl, 6·75 mm.; spiral angle, 60°; sutural angle, 125°.

Note.—Figs. 5 and 5*a*, being drawn from a laterally compressed specimen, show a rather greater breadth and spiral angle, and a more transversely elongated aperture than this form really possesses.

Affinities.—In its general form and ornamentation this shell appears almost identical with one (viz. fig. 6) of the figures of D'Orbigny's *Turbo subduplicatus* (Pal. Fr. Terr. Jur. vol. ii. p. 339, pl. 329, figs. 1–6), a species which, according to that authority, is synonymous with *Trochus duplicatus*, Sow., *Turbo duplicatus*, Goldfuss, *Turbo plicatus*, Goldfuss, and *Turbo Palinurus*, D'Orb. We are, however, confronted with the fact that the Northamptonshire fossil is certainly not a *Turbo*, but a *Trochus*.

The aperture of the particular form (*l.c.* pl. 329, fig. 6) which is so like our specimens is not shown, but the author defines its character in this very variable species of his as "round, with a broad thickening over the columella." The question arises, was the aperture of this particular shell (*l.c.* pl. 329, fig. 6) hidden or imperfectly shown, and has D'Orbigny mistaken its genus in consequence, or has he and Goldfuss also (Petr. Germ. vol. iii. p. 95, pl. 179, fig. 2) misinterpreted the character of this portion of these shells generally, and thus of the genus, from having had to deal with imperfectly-preserved specimens?[1] The description and figure of *Trochus duplicatus*, Sow., which give the aperture as quadrangular (Min. Conch. vol. iii. p. 181, t. 181, fig. 5), indicate that Sowerby's type was a genuine *Trochus*. The species *Trochus duplicatus*, Sow., is therefore good, and must stand. If Goldfuss and D'Orbigny were correct in their respective *specific* identifications of *Turbo duplicatus*, and *Turbo subduplicatus*, with Sowerby's type, they have both erred in their *generic* appellation. However this may be, I consider the Northampton fossil distinct from all these, with the probable exception of the particular shell figured by D'Orbigny as *Turbo subduplicatus* (*l.c.* pl. 329, fig. 6), which—relying upon the vertically truncated whorls and spinose and widely-channelled double-keel—I consider distinct from the other forms figured by that author (*l.c.* pl. 329, figs. 1–5).

Geological Position and Locality.—Upper Lias, zone of *Am. communis*, New Railway, Weedon and Dodford, near Daventry, Northamptonshire.

[1] The matter is complicated by D'Orbigny describing a typical *Trochus duplicatus*, Sow., in another part of the Pal. Franc. (Terr. Jur. Gast. ii. p. 275, pl. 313, figs. 5–8) under that name.

TROCHUS NIORTENSIS, D'Orb. Pl. V. Figs. 6, 6*a*, 6*b*.

1850. D'Orb. Pal. Franc. Ter. Jur. vol. ii. Gast. p. 282, pl. 315, figs. 5—8.

I recently obtained a little shell from the Marlstone Rock-bed of Downcliff, near Bridport, Dorset, which in all essential respects agrees with *Tr. Niortensis*, described by D'Orbigny as having been derived from the étage bajocien (Inferior Oolite) of Niort (Deux Sèvres).

Description.—The following is a translation of that author's description:—"Shell conical, much longer than broad, imperforate. Spire formed of a regular angle, composed of whorls very much hollowed out, striated longitudinally, and marked in the lower portion with oblique costæ tuberculated *below* (*i.e.* posteriorly). The last whorl is convex, striated concentrically above and angular over the sides. Aperture a little depressed and angular. Spiral angle, 49°. Length, 10 mm.; breadth, 8 mm." (D'Orbigny, Pal. Fr. *l.c.* p. 282).

Affinities.—My specimen has a less elevated spire than D'Orbigny's type, being only a little higher than broad, 6:5, with a decidedly greater spiral angle, viz. 60°; the three apical whorls and the spiral angle are a little convex; the costæ, too, are more strongly nodulated at their *anterior* ends and prominent on the upturned keel; the base shows radial as well as encircling striæ; and the aperture is more squarely angulated than in D'Orbigny's figure. These differences are of detail rather than of essence, and not more than might reasonably be expected between individuals of the same species derived from such widely-separated horizons as the Middle Lias and the Inferior Oolite. D'Orbigny speaks of the aperture of his *Tr. Niortensis* as "angular," and in this the description is probably more correct than the delineation, which, like that of too many of the figures in the Paléontologie Française, appears to have received an artistic rounding off or restoration not strictly true to nature.

Obs.—The occurrence of this fossil in the English Lias is of special interest from its being one of those that range into the Oolite.

Geological Position and Locality.—Middle Lias, Conglomeratic Marlstone, zone of *Am. spinatus*, Down Cliff, near Bridport, Dorset.

AMBERLEYA CALLIPYGE, spec. nov. Pl. V. Figs. 7, 7*a*.

Description.—Shell turbinate, thin, imperforate; spiral angle regular; whorls 6–7, only slightly convex, the greatest diameter of the whorl is attained a little behind the anterior suture, whence it falls rapidly thereto, thus giving a slight tabulation; sutures narrow, but clearly defined; last whorl relatively large, long and inflated; base very convex; aperture broadly ovate; outer lip thin, with its inner margin very finely crenated; inner lip slender, extending somewhat over the columella, vertical, but arching forwards towards its angular junction with the outer lip at the anterior margin, which at this point is patulous and a little effuse. The ornamentation of this handsome shell is elaborate, the whole surface being covered with close-set spirals of small rounded tubercles. On the first 4–5 whorls these granular tubercles are much finer than on the

last 2. The third whorl bears only 4 of these spirals. The penultimate whorl bears 7 granular spirals; of these the sixth from the posterior suture lies on and determines a faint angle, and the seventh is close to the anterior suture; these two rows consist of rather coarser tubercles, and speaking generally the granules get smaller towards the posterior suture; the spirals are separated by about their own breadth from one another, and the individual beads of a spiral from a little less up to rather more than their own width. On the last whorl very finely granulated lines are seen setting in between the rows of coarser granules; there are eight or nine of each series counting from the periphery, whilst the base shows a like number of the coarser spirals (which are more closely set and somewhat finer than those posterior to the periphery), with indications of fine alternating spiral lines.

Dimensions.—Length, 8 millimètres; diameter, 5·75 mm.; length of last whorl, 5·75 mm.; spiral angle, 68°; sutural angle, 125°.

Geological Position and Locality.—Middle Lias, zone of *Am. margaritatus*, Daventry, Northamptonshire.

MONODONTA (TURBO) HUMILIS, spec. nov. Pl. V. Figs. 8, 8*a*, 8*b*.

Description.—Shell small, smooth, spire greatly depressed; whorls 4, flattened and embracing, with linear sutures and scarcely exsert (Fig. 8), but occasionally the whorls are a little convex, the sutures distinct, and the spire slightly raised (Fig. 8*a*). A shallow sulcus encircles the whorls posteriorly; this depressed area is most apparent on the last whorl, and occasionally becomes so marked as to hollow out its whole upper surface, and give an angulated instead of the prevailing obtusely rounded border to the shell; the columella is very short and twisted, it terminates by uniting with a prominent bluntly triangular tooth, which originates at the edge of the inner lip in advance of and reflected over the minute umbilicus. Aperture transversely ovate, rather small and not quite continuous, directed obliquely forwards, and having its outer border slightly constricted by the sulcus. Base almost flat, very slightly convex, more or less wrinkled towards the centre. Under a lens the shell shows numerous close-set lines of growth.

Dimensions.—Height, 2·50 millimètres. Diameter 3 mm.

Geological Position and Locality.—Lower Lias, zone of *Am. oxynotus*, common in the Tunnel waste heaps, Old Dalby, Leicestershire.

MONODONTA (TURBO) LINDECOLINA, spec. nov. Pl. V. Figs. 9, 9*a*, 9*b*.

Description.—Shell small, thick, transversely ovate; imperforate; spire scarcely exsert, and apex obtuse; whorls 5–6, convex, embracing with scarcely visible linear sutures, the last whorl inflated; a shallow sulcus bounds the posterior suture; base slightly convex; the umbilical region, which appears to be covered by a thin shelly callus, is encircled by a more or less prominent semicircular ridge which runs nearly from the posterior to the anterior inner margin of the aperture; aperture almost exactly circular, oblique, the last whorl slightly

disjoined from the penultimate posteriorly at the aperture; columella very short, and twisted horizontally, terminating in a prominent bluntly-pointed tooth, in front of which is a narrow groove. The shell is smooth and shining, but under a strong lens its whole surface up to the basal ridge above referred to is seen to be covered with numerous fine encircling striæ, and still finer curved radial striæ.

Dimensions. — Height, 4 millimètres; diameters, 5 mm. and 5·75 mm.

Geological Position and Locality.—Upper Lias, zone of *Am. serpentinus*, Lincoln.

EXPLANATION OF PLATE V.

FIG. 1, a, b, c. *Trochus Dalbiensis*, sp n.—Lower Lias, zone of *Am. oxynotus*, Old Dalby. Back and front views and base enlarged twice, penultimate whorl enlarged six times.

„ 2, a, b, c. *Trochus Thetis*, Mün.—Lower Lias, zone of *Am. oxynotus*, Old Dalby. Back and front views and base enlarged twice, penultimate whorl enlarged six times.

„ 3, a, b. *Trochus Cricki*, sp.n. — Middle Lias, zone of *Am. margaritatus*, Daventry. Back and front views enlarged three times, penultimate whorl enlarged six times.

„ 4, a. *Trochus sagenatus*, sp. n.—Upper Lias, Watford. Back and front views, enlarged three times.

„ 5, a. *Trochus Northamptonensis*, sp. n.—Upper Lias, zone of *Am. communis*, Weedon. Back and front views enlarged twice.

„ 6, a, b. *Trochus Niortensis*, d'Orb.—Middle Lias, zone of *Am spinatus*, Down Cliff. Front and basal views enlarged three times, penultimate whorl enlarged six times.

„ 7, a. *Amberleya Callipyge*, sp. n.—Middle Lias, zone of *Am. margaritatus*, Daventry. Front and back views enlarged three times.

„ 8, a, b. *Monodonta humilis*, sp. n.—Lower Lias, zone of *Am. oxynotus*, Old Dalby. Front, back, and apical views enlarged four times.

„ 9, a, b. *Monodonta Lindecolina*, sp. n.—Upper Lias, zone of *Am. serpentinus*, Lincoln. Back and front views enlarged twice, portion of penultimate whorl enlarged six times.

„ 10, a. *Cerithium trigemmatum*, sp n.—Lower Lias, zone of *Am. oxynotus*, Old Dalby. Back and front views enlarged six times.

„ 11, a. *Actæonina ferrea*, sp. n.—Middle Lias, zone of *Am. spinatus*, Tilton. Back and front views enlarged three times.

„ 12, a. *Cylindrites æqualis*, sp. n.—Middle Lias, zone of *Am. spinatus*, Tilton. Front and back views enlarged twice.

„ 13. *Alaria Hudlestoni*, sp. n.—Lower Lias, zone of *Am. Bucklandi*, Bitton. Front view enlarged three times.

„ 14. *Alaria semicostulata*? Piet et Eug. Desl.—Upper Lias, zone of *Am. serpentinus*, Dodford. Back view enlarged twice.

„ 15. „ „ ?—Upper Lias, Chipping Warden. Front view enlarged twice.

(*To be continued.*)

II.—The Water-Supply of East Kent, in Connection with Natural Springs and Deep Wells.

(Being the substance of a Paper read before the East Kent Natural History Society.)

By George Dowker, F.G.S.

THE numerous demands made upon our underground water-supply, both for sewage and sanitary as well as brewing purposes, render the subject of my paper a matter of deep and serious importance.

I shall set forth in the first place the rise and course of the rivers,

and in the next place the wells, especially the deep ones in the Chalk area; and I propose to show the connection between the height of the springs and the rainfall of the district.

Although I have chosen for the title of this paper "The Water-supply of East Kent," I must premise that the area to which I shall confine my remarks is chiefly East Kent as represented by a line from West Hythe to Whitstable and eastwards, and generally to that part of Kent included in the new one-inch maps, numbered Sheets 273, 274, 289, 290, 305, 306, which combined will form a very good map of reference to my paper.

The well-sections are many of them unpublished, but my remarks will chiefly be directed to their water-level rather than their geological features.

The section I have constructed from West Hythe to the north of Canterbury will show the general dip of the beds of the whole area, and define approximately the thickness of the underlying beds: I say approximately, for the beds below the Chalk vary in relative thickness, and between the Gault and the Wealden beds we may expect to find (after the facts revealed in the deep well-section at Dover Convict Prison, where the Lower Greensand is only represented by 31 feet of clayey sand) no certainty as to thickness or character.[1]

The bed called Upper Greensand between the Gault and Chalk Marl is barely represented in East Kent, and the base of the Chalk Marl, which (in all the sections I have met with) has been so squeezed and contorted that no definite thickness could be assigned to it, and some 50 feet of the Lower Chalk resting on the Gault is an alternation of sand and clay which for the most part retains water. It is from this bed, probably the upper part of it, that we find the springs thrown out all along the southern edges of the escarpment of the Chalk. For the details of these beds Mr. Hilton Price's paper on the beds between the Gault and the Upper Chalk may be consulted.[2]

The rivers of this district are the Stour, the Little Stour, and the Dour.

The Stour has two branches, which both take their rise from numerous springs which issue from the Chalk escarpment of the Weald, mostly between the Chalk and Chalk Marl, or the latter and the Gault. The southern source of the Stour is close to Postling Church, where a strong spring rises at about the elevation of 330 feet above Ordnance Datum. Thence it flows in a north-westerly direction receiving various tributaries; strong springs at Horton Park, Stouting, and Brabourne, the strongest springs in each case rising at the level of 300 and 350 feet. The water is highly charged with carbonate of lime, and travertine (calcareous tufa) is deposited. Thence, flowing westward by Ashford, it is joined by another branch, rising near Lenham Church and Westwell, and so flowing in an opposite direction to Ashford. Here the united streams cut through the Chalk escarpment, and flow as one river between Wye, Godmersham, Chilham,

[1] See Quart. Journ. Geol. Soc. vol. xlii. p. 36.
[2] Quart. Journ. Geol. Soc. vol. xxxiii. pp. 431.

Chartham, and Canterbury. Here the river is fed by several strong springs issuing from beneath the drift gravel and clay beds of the Stour and lateral valleys. At Canterbury, and thence towards the Isle of Thanet, there are many springs, which rise in the alluvium of the valley on either side, in the form of circular deep conical pits, which are locally called "Nicker-pits"—a name of Saxon or perhaps Celtic derivation. As the water from these pits is highly calcareous, it probably is likewise derived from the Chalk, or flows between the Chalk and Lower Tertiary beds. Such springs occur at Chartham and at Canterbury, where one goes by the name of the Silver Hole, and is situated near White Hall. It was proposed by Mr. Pilbrow, the engineer, to utilize this spring for the water-supply of Canterbury. Again, at West Bere, on either side of the river, like springs are met with.

The Little Stour, which in the upper part of its course constitutes the *Nailbourne*, takes its rise at a very short distance from the source of the Great Stour, at Postling Church, is derived from the same range of hills, and has its first spring at Etching Hill, which is about one mile south of Postling Church; thence it flows through the Elham Valley, by Lyminge, Elham, Barham, Bishopsbourne, and Beaksbourne, where it forms a *permanent* stream, flowing thence to Wingham, through Littlebourne, Ickham and Wickham. At Wingham it is joined by a branch stream fed by strong springs ("Nicker-pits") at Danbridge, and by another stream running along the Tertiary escarpment by Ash towards Woodnesborough; at the latter place there are large "swallow-holes" which absorb the water from the surface and convey it some distance underground. Passing Wingham these streams unite their waters in the Little Stour, which flows parallel with the Great Stour, till their waters finally unite at Stourmouth; from which place the Stour (formerly the Wantsum) flows in a very circuitous course round to Sandwich, where it bends upon itself and flows out to sea at Pegwell Bay.

The Dour, the next river, has two heads, one a little above Ewell, at a place called "Little Waters," and another southward towards Alkham, which rises at an elevation of about 300 ft. O. D. The Alkham Valley receives the drainage of the higher hills, running as a "Nailbourne," these two streams unite at River, and thence, as the Dour, flow out to sea through Dover Harbour. The waters of the Dour are highly calcareous, and deposit travertine. Large quantities of this substance have been found in the Dour Valley, which formerly appears to have received a much larger quantity of water.

To the north of Canterbury in the Tertiary area of the district the chief stream is one which rises, in the Blean Woods near Dunkirk, at an elevation of about 200 ft. O.D., and flows in a north-easterly direction to Chislet, where it flows through a valley called the Nethergong, and thence out to sea northwards by Reculver.

A similar small stream, rising near the same place as the last, flows northward out to sea at Swalecliffe, and a third stream issues from the Blean Woods, and flows into Whitstable Bay by the Graveney marshes.

Over the Tertiary area from Deal to Sandwich are several strong springs, which are partly used in the Delf, an artificial water-course, constructed to supply the town of Sandwich with water. One of these rises at Northbourne, receiving there the drainage of the Chalk valleys which run from west to east: this Northbourne stream empties into the Stour near Sandwich Haven. At Eastry another similar spring occurs, flowing in a like direction, and receiving in the same way the underground drainage from the Chalk valley running towards Dover.

In the Isle of Thanet there are no streams of any importance; but one occurs at "Great" and "Little" Brooks End, and runs north-west into the sea near St. Nicholas, while another small brook is found eastward of Minster, emptying into Pegwell Bay; springs issue near the "Sportsman," and from the Thanet beds of Pegwell Bay cliff, in these instances apparently from the Tertiary beds.

Between West Hythe and Folkestone, south of the Chalk hills, are several springs. I would particularize those at Sandling Park and Saltwood, taking their rise from the *Lower Greensand strata*, and flowing out to the sea at Hythe. Similar smaller streams are met with at Newington and Cheriton, while another occurs at Lymne.

By the seaboard from Folkestone to Deal many springs are tapped by the sea-cliffs. Among these I would mention a strong spring at Lydden Spout, which issues from the Chalk Marl, about 15 feet from the base of the cliff, which is about 400 ft. in height. The bed from which this water issues is No. V. bed in Mr. Price's section, 48 feet above the Gault.[1] At St. Margaret's Bay are some very strong fresh-water springs below high-water mark.

The way in which the Chalk strata absorbs, retains, and gives out the rainfall is strikingly illustrated in the wells and "Nailbournes" of the Chalk, to which I wish here to draw attention. Details of the Petham Nailbourne are to be found in the Proceedings of this Society for 1880.[2] I have before mentioned the source of the Lesser Stour as taking the character of a Nailbourne from Etching Hill to Beaksbourne. After a wet season the springs rise, as is apparent by the increase of water in the wells; those situated on the highest level being the first to show it, then successively the springs rise in the wells lower down the valley, till they overflow, or discharge their waters as a periodical stream; this stream runs down the course of the before-mentioned valley till it joins the permanent stream at Beaksbourne. After excessive wet seasons the stream comes from the highest level, but at other times lower down. It is evident, however, that the water is flowing as an underground stream long before and and after it appears at the surface. In proof of which I would mention the following facts. After a very wet season the stream flows all the way down the valley from Etching Hill Pond; at other times it flows only above ground from Lyminge Pond; while at dry seasons it flows above the ground only low down the valley at Beaksbourne. After some wet winters the

[1] Q.J.G.S. vol. xxxiii. p. 431.

[2] See Mr. Hammond's paper, E. K. Nat. History Society, 1880.

Nailbourne may run for two years in succession; on other occasions it may not appear for two, three, or four successive years.

Matthew Bell, Esq., writes to me to the effect that in dry seasons his ponds became dry when the Nailbourne was not running, and being convinced that all the time at Bourne Park the water was finding its way down below ground, he caused a trench three feet wide to be sunk across the valley, through the underground stratum of gravel (which he then ascertained to be about 12 to 15 feet in thickness), into the Chalk below, and then filled this trench with stiff puddle, forming an underground dam. The water, as he expected, immediately began to rise, and the sheet of water opposite his house has never been dry since. A reference to the section which I have prepared to illustrate this paper will perhaps explain the action of this Nailbourne better than a mere verbal description. It will be seen that the beds dip at a considerable angle from south to north; at the former the impervious beds of Chalk Marl and Gault Clay cause the water to gravitate in the porous Chalk strata from south towards the north. The water from the Chalk is derived in the first instance from the rain falling on its surface. This takes a considerable time to find its way down to the *impervious* bed; and, after doing so, to spread laterally through the surrounding strata. It is evident that when the Chalk is *saturated with water*, the water-level is correspondingly raised. It happens that it is some time after the abnormal rainfall, before it affects the water-level of the wells, and consequently before the lower strata become saturated with water. When this is the case, the water finds its way out at the surface, and runs down the valley. It may at first sight appear strange that springs should break out at Postling and Horton, as the beds dip in the contrary direction to the flow; but if you consider that the impervious beds of clay there come to the surface, and the rainfall takes a long time to expand laterally through the Chalk, you will understand that it will here find vent where there is the least resistance.

An examination of the section will show also that the water-level by no means corresponds with the height above the sea-level (a very prevalent error). It will be seen that the water-level in the wells at Acrise, Horton, Elmsted, and Wootton, stands at a level some two hundred feet or more above those at Canterbury. These well-sections are placed to scale at their respective heights, and the water-level of the wells is shown by a shaded line. Most of these wells are dug in the Chalk, not bored, and many of them have been deepened in dry seasons, so that in this case the well depths represent pretty nearly the ordinary water-level in dry seasons; for it is impossible to get these wells sunk to any considerable depth below the point of saturation or water-level in the Chalk. For instance, Mr. Collett, of Elmsted Rectory, who has dug a well 277 feet deep, states: "The springs rise and fall here in a wonderful way; they are usually highest in May, and fall till January, when they begin to rise again. In 1884, Jan. 13, the well was dry, next day it rose 14 feet; the water varies in height from 13 to 63 feet." Mr. Metcalfe, of Upper

Hardres Rectory, writes, "This well was formerly 300 feet deep, but failed in the dry seasons of '56 and '58, when it was deepened 60 feet. The water-level lowers in autumn from 20 to 30 feet."

The Chalk area is by far the largest in this district, and, exclusive of the Isle of Thanet, equals about 296 square miles. While the area of the Tertiary beds is about 158 square miles.

The rainfall of the district is subject to considerable variation, and more statistics on this head are needed. At Sheldwich the average rainfall for three years 1883 to 1885 equalled 25·99 in. At Canterbury for 1884 it was equal to 20·83 in. At Ramsgate for three years from 1883 to 1885 = 21·81 in. While at Horton Park I have for 1883 above 30·00 in. It must be remembered that the last three years were exceptionally dry ones.

One inch of rainfall represents about 100 tons of water to the acre. A portion of this is lost by evaporation, and some passes away underground to sea; the remaining portion constitutes our available supply in rivers and wells.

A consideration as to the permeability of different beds, and their capacity for retaining water, will form an important element in our calculation. We may consider the Chalk area as the most important, not only as the chief water reservoir, but as constituting by far the largest portion of the district, and it will be found that it is throughout its extent extremely permeable when not saturated with water, down to a short distance from the Gault. The large supplies of water required for the Canterbury Waterworks, the Chartham Asylum, the Canterbury Breweries, the wells for drinking water at Ramsgate, Margate, and Dover, are all derived from this formation. In the case of the deep boring for the Convict Prison at Dover, made during this year, when strata were pierced to the depth of over 900 feet (penetrating both Gault and Lower Greensand), the water-supply was chiefly, if not entirely, derived from the upper three hundred feet, all in the Chalk. The time taken by the water to reach the line of saturation in this Chalk area appears to be about three or four months, and the height of the springs varies in proportion to the rainfall.

The Chalk area is in some places capped by impermeable beds of clay, as at Swingfield Minnis, but the clays and gravels over the Chalk are for the most part permeable. North of Canterbury, over the Tertiary area, the permeable beds are the sandy portions of the Old Haven, Woolwich, and Thanet beds; the lower parts of the latter, however, are impermeable. Above these the London Clay and the clay and gravel beds of the Blean district are impermeable.

A narrow tract of land below the escarpment of the Chalk Downs, stretching from Folkestone to Wye, is composed of impervious Gault and pervious beds of the Lower Greensand. In many of the wells, after piercing the Gault, the water flows up to, or over the surface. In this area the water from the Sandgate beds of the Lower Greensand is bad, being largely impregnated with iron. I have very few data relating to the wells of this district, which is, however, of little importance in the general survey of the water supply.

Mr. W. Whitaker, B.A.Lond., Assoc. Inst. C.E., F.G.S., of H.M. Geological Survey, has kindly placed at my disposal some well-sections not before published, chiefly that of the Herne Bay Waterworks at Ford and the Whitstable Waterworks, which are in the Tertiary area north of Canterbury. But it is not certain from these data whether the water is derived from the Thanet Beds or the Chalk. In the case of Whitstable, at a height of 48 feet above Ordnance Datum, the well, 400 feet deep, pierced the London Clay at 69 feet, the Tertiaries at 240 ft., and penetrated the Chalk 160 feet. The water-level is stated to be 35 feet down, and the yield 220 thousand gallons daily. And in the case of Ford, reaching a total depth of 260 feet, piercing the Lower Tertiaries at 110 feet, and penetrating the Chalk 50 feet—the water-level standing 26 feet down. From which facts it seems that the Chalk in both cases was the source of the supply.

The well-sections in the Isle of Thanet, which have (with the exception of one at Mr. Cobb's Brewery, Margate) been sunk but little below the sea-level, have only yielded water at about that level. In the case of Mr. Cobb's well, which reached a depth of 317 feet, no spring was met with. Artesian wells at Minster at a low level, piercing the Thanet Bed to some 20 feet or so into the Chalk, yielded water springs flowing to the surface.

The permeability of the Chalk in Kent was shown some years ago by an old member of our Society, Mr. Bland, of Sittingbourne, in some tables which he published showing how one well was influenced by another, and how they all fluctuated with the rainfall of the seasons. Mr. Prestwich has in his memoirs[1] made use of it, and I am indebted to the Rev. C. J. Wimberley, of Sibertswold Vicarage, for a copy of this interesting paper. His conclusions with respect to the permeability of the Chalk have been corroborated in all the observations I have made, and the truth cannot be too often repeated to those who are engaged or interested in sanitary matters. It must be of the first importance to consider this in relation to the sewage and health of towns. Sewage matter will contaminate a large area of Chalk, if precautions are not taken.

The section I have made would show how regularly the lower beds dip towards Canterbury; but if I had continued the section to Whitstable nearly in the same line, it would be apparent that the Gault must rise, or there would be an enormous thickness of Chalk to be accounted for had the Gault continued at the same dip. It is assumed that the bore at the Chartham Asylum touched the Gault. Mr. Whitaker places the bottom of the bore at that horizon. From the specimens I have seen at the Canterbury Waterworks, I doubt if they quite reached the Gault. There seems also to be a slight synclinal of the Thanet beds in the valley of the Stour east of Canterbury—the Isle of Thanet being on an anticlinal.

It would seem as if the Lower Greensand in this neighbourhood cannot be reckoned upon as a source of water-supply, firstly, because

[1] "The Water-bearing Strata of the Country round London," and "Manual of Geology."

the water is not good, and secondly, because there is no high land of this formation to receive the rainfall, nor is it certain that it would be met with in any thickness east of Dover.[1]

The slight anticlinal ridge of the Thanet Chalk has yielded water for the present supply of Ramsgate, Margate, and Broadstairs; but in dry seasons the supply has not equalled the demand, and supplementary wells have been sunk; these, however, all derive their supply from the exceedingly porous beds of the Upper Chalk, the wells not reaching much below the sea-level, about which point the line of saturation of the Chalk is there reached. From the fact that one of these, the Southwood Waterworks near Ramsgate, became brackish from the influx of sea-water, the engineers of these waterworks appear to have been afraid to sink deeper in the Chalk. It is proverbially foolish to prophesy unless you know; but I would venture to suggest that the future water-supply of Thanet must be sought for in a well reaching down nearly to the Gault. For though there is every appearance that the whole depth of the Chalk strata of Kent are to be found here (the Thanet beds reposing on the higher beds at Margate, St. Peter's, and Broadstairs), yet there should be no difficulty in piercing the Chalk, and I should expect an unlimited supply of good water would be found in the Lower Chalk. Should such be the case, there would be no danger of its being contaminated with sea-water, if a site were chosen not too near the sea, or directly in a line of fault. If the stratum pierced was in a state of saturation, there would be no reason to fear that sea-water would replace the fresh.

One great advantage of the water derived from deep Chalk strata is its great purity, the only drawback being its exceeding hardness, from the presence of bicarbonate of lime; this may, however, be got rid of by adopting the admirable method employed at Canterbury, of passing lime water in certain proportions into the fresh pumped water, which, uniting with the excess of acid in the bicarbonate of lime in solution, precipitates it as an impalpable powder, and at the same time killing all organic impurities and precipitating them with the lime.

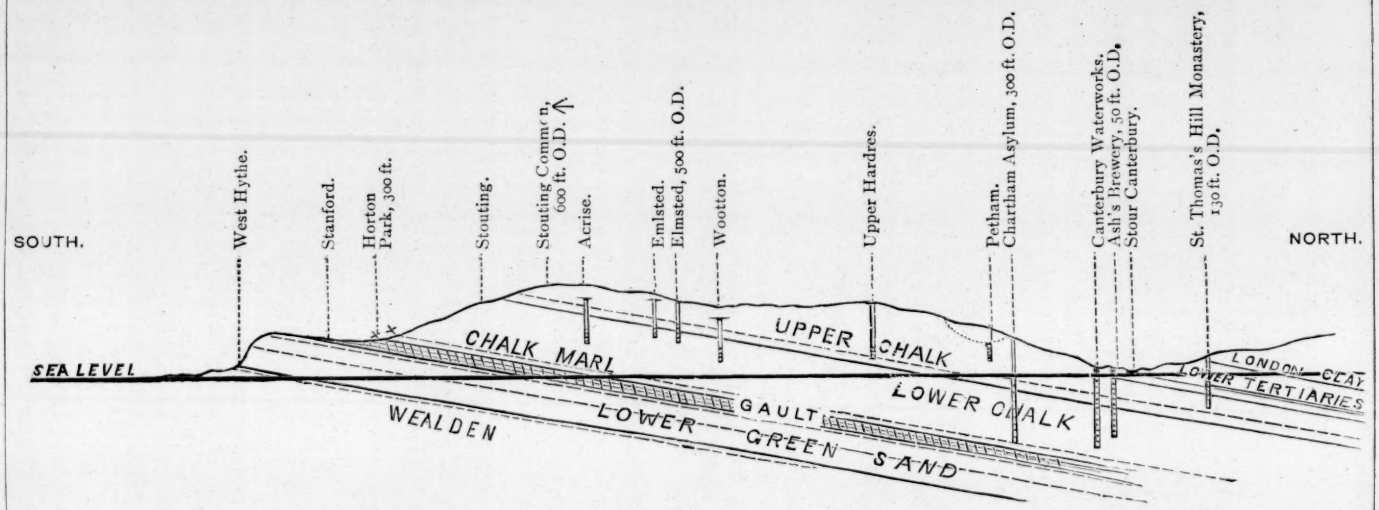
It now only remains for me to explain the supplementary section and well notes which have been placed at my disposal. Mr. Bland's paper, already alluded to, is entitled, "Measurements of the Altitudes of the Hills and Valleys and the Depths of Wells through a Part of Kent, undertaken for the purpose of ascertaining the Height of the Springs above the Sea-level," and referring chiefly to the Chalk in and around Sittingbourne in the years 1827 and 1828, with the rainfall and state of the weather from 1819 to 1829. Privately printed at Sittingbourne. For the loan of this interesting paper I am indebted to the Rev. C. J. Wimberley, Sibertswold Vicarage.

Notes on the Petham Nailbourne from 1772 to 1869. Communicated by Mr. James Reid, of Canterbury. "The Nailbourne came into Shamford Street, Feb. 22, 1772, and continued to run through the street till June 16, 1772. It came into the street again, March 7, 1774, and continued running till June 28, 1774. It came into

[1] See section in Mr. Whitaker's paper, Quart. Journ. Geol. Soc. vol. xlii. p. 36.

To illustrate Mr. Dowker's paper on the Water-supply of East Kent, in connection with Natural Springs and Deep Wells.

SECTION FROM WEST HYTHE TO CANTERBURY, ABOUT 17 MILES. GENERAL DIRECTION, SOUTH TO NORTH.



* Springs issue from this level south.
The wells, bottoms and tops are to scale above and below Ordnance Datum level.
The stations are nearly on the line of section except Acrise.

Horizontal Scale three miles to one inch. Vertical Scale 1200 feet to one inch.

GEORGE DOWKER, F.G.S., del.

Situation.	Authority.	Surface Height above O.D.	Depth.	Water Level from Surface.	Remarks.
		FEET.	FEET.	FEET.	
Whitstable Waterworks	W. Whitaker	43½	400	35	Tertiaries to 240 ft. Chalk, 160 ft. Bored.
Ford, Hoath	W. Whitaker	50	260	26	Tertiaries, 110. Chalk, 50. Bored.
Canterbury Monastery	W. Whitaker	120?	310	105	Tertiaries, 208. Chalk, 102. Bored.
Canterbury Waterworks	J. C. Homersham, C.E.	47	509	19	In Chalk, Greenish Chalk, 26½ ft. Yielding 900,000 gallons per diem. Bored.
Canterbury Dane John	Kentish Gazette, 1886	50?	400	18?	To Chalk, 24 feet. Yielding 2500 gallons per hour. Bored.
Chartham Asylum	W. Whitaker	300	740	230	Chalk 734 ft. Gault 5 ft. Bored.
Upper Hardres	Rev. F. Metcalfe	400	360	300	Water lowest in Autumn 20 to 30 feet. Dug.
Hardres School	Ditto	429	200	Dry at times.	The former deepened 60 feet in 1856. Dug.
Elmsted Vicarage	Rev. G. A. Collett	500	243	180	Varies much. Dug.
Elmsted	Rev. G. A. Collett	514	277	—	
Sibertswold		400	300	288	Water generally 12 feet deep. Dug.
Wootton Rectory	J. P. Hambrook	420	333	290	Stands at — varies greatly. Dug.
Wootton Denton	Rev. J. Wimberley	—	—	—	Varies from 13 to 63 feet. Dug.
Acrise Place	W. A. Mackinnon	500	240	—	Varies but never fails. Dug.
Stouting Rectory	Rev. Upton	350?	12	—	Highest in January, lowest in October. Dug.
Monks Horton	J. Kirkpatrick, F.G.S.	386	—	—	Surface springs at 300 feet, O. D. Dug.
Dane Farm, Petham	Ditto	300	260	240	Depth of water 20 ft. Dug.
Dover Convict Prison	W. Whitaker	280	916	315	Water yielding 18,000 gals. per diem. Bored.
Margate	G. Dowker	—	374	—	No spring of water met with. Bored.
Ramsgate Waterworks	J. T. Hillier	118	150	10?	Yields 900,000 gallons per diem. Dug.
Ramsgate Hersen J.	J. H. Hillier	100	80	—	Brackish, influenced by the tide.
Stourmouth	G. Dowker	20	159	11	To Chalk 138 feet.
Sandwich	W. Whitaker.	15	62	20	
Canterbury Clergy Orphan Asylum	G. Dowker	140	145	120	All in Tertiaries. Bored.

the street again Jan. 12, 1775, and again Feb. 26, 1776. This Nailbourne ariseth at Dean, in the parish of Elmsted, and at Duck Pit in the parish of Waltham. This by Thos. Page." From other data this Nailbourne ran in Jan. 1860, Feb. 1861, 1864, to June, 1865, and slightly in 1866, 1869, and Jan. 1873.

Notes on a Well at Elmsted Vicarage. Communicated by Rev. G. A. Collett. "This well was sunk in the Vicarage garden in 1884, at an elevation of 500 feet O.D. Water was first reached at 180 feet. Waiting for this to lower, the well was continued to 243 feet, where a good head of water was met with. The strata met with were firstly, 11 feet of diluvial matter, stones, clays, etc., called locally 'clay pillars.' All below this, Chalk without flints, with joints few and far between, the Chalk so hard that it had to be blasted with gunpowder, no need to 'steen.' We sent up at 58 feet some palatal teeth of fish, and lower down fragments of *Inocerami*. Below 220 feet the Chalk was more jointed and easier worked. The springs rise and fall here in a very wonderful way, they are usually highest in May and fall till January, when they begin to rise again. In December, 1884, I ran my well dry, but kept sounding it in January, 1885, expecting water. On the 13th it was dry, next morning I found fourteen feet of water, which soon increased to 40."

In the tabulated list of wells appended, I have given the height above O.D., the depth of well, and the water-level (where this information is given), but in most cases, especially in bored wells, the latter is not very conclusive. For other particulars of well-sections I must refer my readers to the Memoirs of the Geological Survey, vol. iv. pt. 1. by Mr. W. Whitaker, B.A., F.G.S., and the Quarterly Journal of the Geological Society, vol. xlii. p. 26. I have confined my observations chiefly to the water supply.

I am indebted to those gentlemen whose names appear in the Appendix of Well-sections (p. 211) for much valuable information.

III.—The Gneissose-Granite of the Himalayas.

By Colonel C. A. McMahon, F.G.S.

Introduction.

THE cause, or causes, which result in the foliation of igneous rocks is a subject which at present occupies the attention of many geologists, and seems likely, in the near future, to lead to some discussion. In view of this, a short account of the foliated granite of the Himalayas may be of interest. It may be as well, however, to preface my remarks by saying that I believe that foliation may be produced in several distinct ways, and the explanation which I offer of the mode in which the foliation of the Himalayan granite has been brought about is only intended to apply to the case of that granite.

In the following pages I propose to give a brief summary only of some of the more important results worked out in detail in a series of papers published in the Records of the Geological Survey of India; and to add thereto a brief consideration of the question whether the foliation of the gneissose-granite of the Himalayas was, or was

not, produced by pressure-metamorphism, a point not touched on in my published papers.

As the Himalayas cover a large area, I shall limit my remarks almost exclusively to the rocks in the neighbourhood of Dalhousie, a sanitarium in the mountains nearly due east from Lahore, the capital of the Panjab. Want of space obliges me, however, to make my observations on the stratigraphy extremely brief. Any one requiring more detailed information will be able to find it in the volumes of the Records of the Geological Survey of India.

In the neighbourhood of Dalhousie the gneissose-granite appears in two bands striking in a north-westerly direction. The inner band at Dalhousie itself is six miles and a half in thickness; further to the south-east the thickness increases to eleven miles, and this broad belt extends for some hundreds of miles in a south-easterly direction. In its north-westerly extension from Dalhousie the band suddenly contracts to a width of two hundred and fifty yards: but twenty-one miles further on it expands again as abruptly as it contracted.

This outcrop is in contact along both margins with Silurian rocks; those along its eastern margin being older, and those along its western margin younger Silurians. The interpretation which I have put on this section is that the granite has risen through the axis of a flexure that resulted in an overfold fault.[1]

The outer band of gneissose-granite, roughly speaking, runs a course parallel to the western margin of the inner band, being divided from it by a broad belt of Silurian beds. To the south of Dalhousie it dies out altogether. Its general width is between four hundred and five hundred feet; but to the north-west of Dalhousie it widens out to several thousands of feet in thickness. Along its eastern margin it is in contact with Lower Silurian, or Cambrian, mica-schists (no fossils have ever been found in them, so their precise age cannot be determined); and along its western margin with limestone and slaty beds of Carboniferous age. The latter are not greatly altered rocks; the limestones are never more than sub-crystalline; and though the slaty rocks have often a thin micaceous glaze, they are sometimes shaly in appearance; and are frequently so highly charged with carbonaceous material, and so coal-black in colour, that they have from time to time, in various parts of the Himalayas, raised fallacious hopes of finding coal in the minds of non-geologists.

The strike of the Silurian and Carboniferous beds conforms to that of the granite, following all its curves. The beds in contact usually dip into the granite; but occasionally dip away from it.

The Gneissose-Granite.

The gneissose-granite is almost always decidedly porphyritic, though it occasionally passes into a fine-grained non-porphyritic rock. The matrix is usually a granite of moderately large grains (it is

[1] A geological map of the Dalhousie area and diagrammatic sections explaining it will be found at page 110, vol. xviii. Records Geol. Survey of India.

never coarse-grained), but occasionally it becomes so extremely fine-grained that the rock assumes, to the unaided eye, the appearance of a felspar porphyry. In the perfectly granitic varieties the porphyritic crystals of felspar, which sometimes attain a length of from three to three and a half inches, orient in all directions, and present sharply rectangular forms. From the porphyritic-granitic and non-porphyritic-granitic varieties the rock passes by gradual transitions into a more or less foliated granite. The passage from one variety to the other is often apparently capricious; but even in the most perfect granitic masses a tendency towards foliation may generally be observed at its edges.

Speaking generally, the granite of the inner outcrop is foliated along both margins; and the foliation becomes intense where the band contracts, on the north side of the river Rávi, to a width of two hundred and fifty feet. At this point it passes, on its western margin, into what, from its macroscopic aspect, would be called a mica-schist.

The outer band of gneissose-granite is intensely foliated. It does not indeed pass into a mica-schist; but it not unfrequently looks, viewed macroscopically, as if it had been flattened under a steam roller.

Joints are abundant; and they frequently simulate bedding; but true bedding is not to be seen.

The granite is composed of orthoclase, plagioclase, microcline, quartz, biotite, and muscovite. In some localities biotite predominates—in others muscovite. Magnetite, garnets, and apatite are sometimes present; whilst schorl is rarely absent from the granitic varieties. The presence of ilmenite may also be inferred from the occasional existence of leucoxene.

Mircoscopic characters of the Gneissose-Granite.

Under the microscope the granite yields abundant evidence of strain, pressure, and shear or traction. The twinning planes of the triclinic felspars are sometimes bent; felspars are frequently cracked, fractured, and occasionally the pieces are pushed over like books on a shelf; whilst crumpled micas may be seen which have been completely bent and one end folded over on the other like a sheet of note-paper preparatory to being placed in an envelope.

A prominent characteristic of every variety of the Dalhousie gneissose-granite, even the most granitic, is the presence of what I have called in my papers by the short term of crypto-crystalline mica. It is mostly a form of muscovite, though the imperfectly crystallized material of biotite is occasionally present in ropy masses. This crypto-crystalline mica varies from a pale-buff to a pale-grey colour, and it has a superficial resemblance to the base of some felsites and rhyolites. In its typical form, though its double refraction is strong, no definite crystals of mica can be made out; and the leaflets, under polarized light, melt into each other and exhibit no definite shape. This crypto-crystalline mica passes into a micro-crystalline condition, in which the leaflets, though of extreme micro-

scopic size, have a distinct individuality of their own. Both varieties will, in the following remarks, be referred to under the term crypto-crystalline mica.

This crypto-crystalline mica is present in all varieties of the Dalhousie granite. It is to be seen in every thin slice under the microscope; and in the foliated specimens it traverses them in strings; sometimes extremely attenuated; at other times widening out into comparatively broad lake-like expanses. It does not run in straight lines, but flows in curves like those of rivers on a map; now approaching each other; now diverging widely; bending sharply at one turn, and making a wide sweep at another. It frequently leads up to, or embraces in its streams, large crystals of muscovite, quartz grains, and other minerals; and it occasionally traverses large felspars. I shall have to allude to this crypto-crystalline mica further on.

Another striking characteristic of all varieties of the Dalhousie granite is what I have termed in my papers fish-roe quartz; that is to say, quartz in grains of microscopic size clustered together in a way to suggest the roe of a fish. This polysynthetic or fish-roe quartz behaves very much as the crypto-crystalline mica behaves; that is to say, in the foliated specimens it flows about in streams round the larger minerals; fills the interstices between larger grains of quartz; and stops the fractures in felspars. I shall have to allude to this further on.

The most important questions which arise in connection with the rock above described are: Is it an igneous eruptive rock? and if so, was the foliation produced prior, or subsequent, to its final consolidation? I propose to consider each point separately.

Evidence of the eruptive origin of the Gneissose-Granite.

In the first place it seems necessary to meet the objection of those who may be disposed to hold the view that it is an ancient, possibly Pre-cambrian rock, which suffered erosion before Silurian times. It would be impossible to discuss this position in detail in a brief article that only proposes to give the results of the author's investigations; but I may say that I carefully considered this point in the field at a time when I had formed no theories about the Dalhousie rock in my own mind, and that I could not discover any evidence to support it. Two considerations seem to offer serious obstacles to the acceptance of this theory. In the first place, erosion which reduced the gneissose-granite from a thickness of eleven miles to that of two hundred and fifty feet would hardly have left a long stretch of this slight thickness without having cut through it altogether; secondly, if this crystalline rock represents an ancient and eroded land-surface, the granite to the north of the Ravi, where its thickness is only two hundred and fifty feet, ought to be a fair sample of the granite two or three miles to the south of the Ravi, where its thickness is six miles and a half; but, on the contrary, the former is a much more intensely foliated rock than any portion of the latter. The thin band of granite north of the Ravi has evidently been sub-

jected to much more intense squeezing than the massive portion, and field observations favour the conclusion that the intensity of the foliation and the narrowness of the outcrop are directly connected with each other.

Without pausing to discuss this question further, I pass on to state briefly the evidence which the rock presents of eruptive origin.

Stratigraphical evidence.—First, the granite has produced a certain amount of contact metamorphism on the rocks touching it. The slates exhibit a marked increase in induration and they pass more or less into a crystalloid condition as they approach the granite. Schorl, garnets, dark mica, muscovite, and magnetite have been formed in the slates by contact action; foliation has sometimes resulted from that action—at other times "spotted schists" have been formed.

Secondly, tongues and intrusive veins have been sent from the granite into the adjoining rocks: in other places the granite appears in sheets between the beds of the sedimentary rocks at some distance from the junction of the latter with the main mass of the granite; and in some cases these sheets, or dykes, have cut through the beds and passed from one horizon to another.

Thirdly, the main mass of the granite appears at different geological horizons.

Fourthly, the granite contains veins similar to those caused by shrinkage on cooling in granites of admittedly eruptive origin.

Fifthly, it contains fragments of slates and schists imbedded in it. A striking photograph, or rather a print produced by the heliogravure process from a photograph, of a schist enclosed in the main mass of the granite, half a mile from its contact with the slates, will be found at p. 175, Records Geological Survey of India, vol. xvii. (with a paper thereon); which, in conjunction with the evidence afforded by the microscope, completely sets at rest any doubts that might have existed, previous to the discovery of this specimen, as to whether or not these inclusions are true fragments of foreign rocks caught up in the granite.

Microscopic evidence.—The evidence afforded by the study of numerous thin slices under the microscope confirms the conclusion arrived at by the stratigraphical evidence, and indicates the eruptive origin of the gneissose-granite. I select the following instances for enumeration:—

First, the presence of microliths containing contraction cavities precisely similar to those in microliths to be seen in undoubted eruptive rocks. As an illustration I would point to fig. 11 of the plate at page 158, Records G.S.I. vol. xvi., which gives the sketch of a microlith seen in one of the Aden lavas, but which serves equally well as an illustration of some of those seen in the gneissose-granites; *vide* Records G.S.I. vol. xvii. p. 60.

Secondly, cracks in microliths formed by contraction on cooling. In some cases the fractured portions have been floated to a little distance from each other. Fig. 5 of the plate at p. 72, Records G.S.I.

vol. xvii. affords a striking illustration of a microlith thus ruptured. Cracks of the character alluded to do not in any case extend from the microlith into the matrix.

Thirdly, opacite embracing and riding on the backs of previously formed microliths. As illustrations I would point to the right-hand figure of fig. 6, plate ii. p. 144, vol. xvi., compared with fig. 13 of plate at p. 158, vol. xvi. Records G.S.I. The former is a representation of a microlith in a Himalayan gneissose-granite, and the latter of one in an Aden lava. The last-mentioned illustration could be exactly matched by numerous illustrations from the gneissose-granites.

Fourthly, stone cavities,[1] in which mineral matter has been deposited on cooling. Compare fig. 18, plate, p. 72, vol. xvii. (a Dalhousie specimen) with figs. 4 to 10, inclusive, plate, p. 158, vol. xvi. Records G.S.I., Aden lava specimens. The presence of clusters of minute microliths sticking to and fringing the *outside* of the Dalhousie stone cavity shows conclusively that this is not a case of schillerization.

Fifthly, stone cavities in which either crystals have been deposited on cooling, or in which mineral matter has caught up and enclosed previously formed crystals. Illustrations, figs. 1, 6, and, possibly, the upper portion of fig. 18, plate, p. 72, vol. xvii. Records G.S.I.

These instances, which are selected by way of sample of the kind of evidence applicable, indicate I think that the gneissose-granite at one period of its history was in a condition of what may be termed —roughly speaking—igneous fusion. That water was, however, to a considerable extent mixed up with the constituents of the rock when it was in a plastic state, and that its condition may be more correctly described as one of igneo-aqueous fusion, is made plain by the examination of thin slices under the microscope. Liquid cavities abound in the quartz of the granite; whilst, it is important to observe, they are entirely absent from the slates in contact with it. The heat produced by contact with the granite appears to have been sufficient to drive the water out of the quartz of the slates and of the siliceous rocks brought within its influence. An interesting illustration of this was afforded by an examination of the crystals of schorl found in the slates in contact with the granite. When these crystals were first formed, they appear to have contained inclusions of air, gas, or liquid; but as the heat increased, and the included matter expanded under its influence, the included gas, or liquid, was forced out to the surface of these crystals and driven off. An interesting illustration of this will be found at fig. 7, pl. ii. p. 144, vol. xvi. Records G.S.I.

Cause of the foliation of the Gneissose-Granite.

A realization of the eruptive character of the rock described in the above pages removes many difficulties from the way of the Himalayan geologist. "Despite the wonders performed by flexure of strata in mountain regions," wrote Mr. Medlicott, the Director of the Geological Survey of India, in his Annual Report for 1883, "the

[1] This is an awkward term; but, as it was introduced by Sorby, I retain it: microscopists know what it means.

structural features presented by this rock in certain cases were impossible of satisfactory explanation on the supposition of its being a really stratified gneiss." But if the eruptive origin of the gneissose-granite be admitted, the further question arises whether the foliation observed in it was produced prior, or posterior, to the consolidation of the rock. In considering this question, I leave out of sight altogether evidence of fluxion structure as being really irrelevant to the question at issue, though I think it material to state that the rock does show very decided evidence of fluxion. Without laying any stress on this fact, however, I think the following considerations prove that the foliation was not produced by pressure acting on the rock after its consolidation.

First, the granite is not always foliated at its contact with the rocks into which it has been intruded; on the contrary, though still porphyritic, it is not unfrequently decidedly granitic along its margin. This fact presents no difficulty to the acceptance of the hypothesis advocated below, but I think it offers an insuperable barrier to the acceptance of the view that the foliation was produced by pressure. Simple pressure will not do: that would not explain the crumpled micas and the very decided evidence of flow or fluxion. Pressure resulting in shear, motion, the development of heat and concomitant chemical and mineralogical action, might possibly account for the fluxion structure; but if shear and motion were established on the grand scale required after the consolidation of the rock, the granitic portions along the margins could not possibly have escaped the effects of this action.

Secondly, the apparently capricious passage from a granitic to a foliated structure in the main mass of the granite is another serious impediment in the way of the acceptance of the theory of dry pressure.[1]

Thirdly, the conjunction of the outer band of gneissose-granite at Dalhousie with the Carboniferous series presents another almost insuperable difficulty. The outer band is the most intensely foliated of all the Dalhousie granite. Parts of it look as if it had been rolled under a gigantic steam roller. Unquestionably it has been subjected to very great pressure, and to either traction, or shearing; and yet this rock is chock and block with little altered black Carboniferous rocks. He who would apply the dry-pressure theory to explain the intense foliation of the outer band of granite, would have to invent a new set of conditions out of his inner consciousness and bring some other rock into position next the granite before he applied the squeeze.

Fourthly, the condition of the long tent-peg-like splinter of schist included in the granite, alluded to above, shows conclusively that the granite at the point where the inclusion was found was not subjected to extreme pressure of the character under consideration after its consolidation. Had it been, the splinter of schist would

[1] I use this expression as a short term to indicate pressure applied *after* the consolidation of a rock, though, of course, I am aware that pressure so applied may produce heat and even fusion.

have been flattened to a wafer. A mere glance at the plate, a photograph reproduced by the heliogravure process, will show this at once.

Fifthly, neither the crypto-crystalline mica, nor the fish-roe quartz, described *ante*, can possibly have been produced by the grinding down of the mica and the quartz in the consolidated rock, or by any analogous process; for, besides the crypto-crystalline mica, and the fish-roe quartz, we have very numerous *large* crystals of muscovite, biotite, and quartz. The muscovite and biotite are large and beautiful specimens of these minerals, and they orient in all directions and at every angle up to a right angle to the strings of crypto-crystalline mica. Mechanical action potent enough to have reduced mica to the pulpy condition of the crypto-crystalline mica would not have left the larger micas untouched. Similarly, the fish-roe quartz not only fills cracks in felspars, and forms a sort of setting to quartz grains, but it meanders about in the interior of large quartz grains, and terminates abruptly inside them, in a way that does not suggest to the observer that he is looking at cracks stopped with micro-crystalline quartz, but rather that the crystallization of the quartz was brought to a comparatively rapid termination towards its close.

Indeed, properly considered, I think the crypto-crystalline mica, and the fish-roe quartz, furnish a clue to the riddle. I may mention in passing that I have observed in a felsite patches of material closely resembling the crypto-crystalline mica mixed up with the quartz and the ordinary felsitic base; but I desire more particularly to refer to a series of rocks which occur in the peninsula of India about eighty-five miles nearly due west of Delhi. We have there a very interesting group ranging from felsites, quartz-porphyries, and granite-porphyries to almost true granites. The felsites appear to be true lavas; and the others, though merging gradually into rocks of plutonic character, are probably more or less directly connected with them. These rocks never show any trace of foliation, or give any indication of crushing. But what is important to note is, that the gradual genesis, so to speak, of the fish-roe quartz may be observed in these rocks. The quartz gradually becomes more and more developed in the felsitic base; it begins to crystallize out in grains of microscopic size, and the grains increase in number, until at last the whole base, or ground-mass, of the granite-porphyries partakes closely of the characters of the fish-roe quartz of the Dalhousie granite. The true explanation of the foliation of the latter rock I believe to be briefly as follows:—The rock had partially consolidated before it was moved into place: large porphyritic crystals of felspar, and numerous micas and quartz grains had formed; it was very much in the condition of a felspar-porphyry, or a granite-porphyry; when, in the course of the earth-movements that were contorting, crumpling, and folding the strata of the Himalayas, this imperfectly consolidated granite-porphyry was forced through the faults that had been formed along the axes of over thrust-folds; the semi-plastic mass was subjected to enormous pressure; the mica was crumpled; the crystals of felspar were cracked and ruptured; and so much of the micaceous siliceous materials as remained unconsolidated were forced into the rents made

in the already formed minerals. The final consolidation took place under conditions of continued strain; but before it was actually accomplished minor and subsidiary eruptions took place which forced new supplies of the granitic material into fissures formed in the previously injected rock, and this fresh material consolidated under conditions somewhat different from those of the first eruptions.

I think this view meets all the difficulties of the case, and that the intelligent reader will with its aid be able to harmonize all the facts stated above without detailed exposition on my part.

IV.—On the Geological History of the Cornish Serpentinous Rocks.

By J. H. Collins, F.G.S.

(*Continued from* Geol. Mag. Decade III. Vol. III. 1886, p. 366.)

III. Rocks Exhibiting but a Moderate Amount of Serpentinous Change.

Botallack Mine.—The dark hornblendic slates of the sea-border of the parish of St. Just are known to many geological tourists. They have been well described by the late Mr. J. A. Phillips,[1] who regards them as consisting of altered killas; and the justice of this conclusion will not I think be questioned by any who have studied the rocks *in situ*; traces of an original lamellar structure are visible even in hand-specimens. Phillips (*op. cit.* p. 322) gives the following analyses of the rock, *a* being from near the surface, and *b* from a depth of 130 fathoms, or far below the sea-level; while *c* is the analysis of a typical Cornish killas (from Polgooth Mine, 100 fathoms from surface): —

	a.		*b.*		*c.*
Water { hygros. ·39 / comb. 2·74 }	3·13	{ 4·12 / 6·97 }	11·09	{ 2·00 / 1·26 }	3·26
Silica	40·22	.....	32·98	...	50·92
Phosphoric acid	·66	.....	trace	.....	—
Titanic acid	·15	.....	trace	.....	trace
Alumina	24·01	.....	16·73	.....	20·79
Ferrous oxide	11·27	.....	13·71	.....	4·92
Ferric oxide	4·21	.....	7·03	.....	13·41
Lime	4·11	.....	4·90	.....	1·62
Magnesia	6·52	.....	11·52	.....	—
Potash	1·67	.....	·72	.....	·93
Soda	3·57	.....	·63	.....	4·03
	99·52		99·31		99·93
Sp. Gr.	2·95		2·82		2·73

Evidently *a* and *b* are in a highly-altered condition; but assuming that they were originally of similar composition, approximating to *c*, it would seem that the deeper-seated rock has been much more altered than the other in the direction of serpentine; it is also softer, lighter, and more serpentinous in aspect. The following is its appearance under the microscope, as stated by Mr. Phillips or as

[1] Quart Journ. Geol. Society, 1875, vol. xxxi. pp. 319-343.

observed by myself. The base is green and transparent; it includes many minute acicular or fibrous crystals of hornblende or asbestos crossing each other in all directions, some in bundles with parallel axes, as if from the partial destruction of a cleavable crystal. In some instances the hornblendic bundles are replaced by a greenish mineral which is possibly chlorite, and there is always present more or less crystalline magnetite. Mr. Phillips says, "It is worthy of notice that while the slates of Botallack are highly magnesian, the sea-water which percolates through them into the workings of the mine has lost three-fourths of its magnesium. Similar effects appear to be produced at Huel Seton, where the amount of magnesia in the rock bounding the great cross-course, which is traversed by the modified sea-water constituting the well-known 'lithia spring,' is twice as large as it is in the normal killas of the locality. The magnesium of the sea-water has in this case almost entirely disappeared." [1]

Terras. St. Stephens.—This is a band of dark and fine-grained rock used locally for roadstone, which is not marked on the 1-inch Geological Map. It is very tough, and often platy in character, owing to an incipient pseudo-cleavage which I take to be an indication of an original bedding now almost obliterated. It has all the appearance of a compact hornblende schist. Thin veins of an asbestiform mineral are often seen in the joints, and occasionally the fibres of this mineral are so interlaced as to result in a kind of "rock-leather" or "rock-felt" sometimes as much as half an inch in thickness. Some of the joints, however, are lined with thin films of serpentine, and in such cases the rock itself exhibits serpentinous change to a depth of an inch or more, so as to be almost indistinguishable from the Botallack rock above referred to. In thin sections, and under a moderate magnifying power, it is seen to be made up of a transparent greenish serpentinous base full of matted crystals of hornblende. The original laminar character of the rock is indicated by many crystals of magnetite and minute patches of viridite. Occasionally, too, fibres of asbestos are visible, and, rarely, minute prisms of apatite.

I made a partial analysis of this rock in 1872, with results as follows:—

Loss on ignition	·92
Silica	45·20
Alumina	19·80
Magnetite	5·01
Ferrous oxide	7·35
Lime	8·00
Magnesia	6·20
Not determined	7·52
	100·00

A very similar rock, probably an extension of the same bed, was opened up some years since at Terras Mine, and described by Mr. J. A. Phillips as a greenstone (Q.J.G.S. vol. xxxii. p. 175).

[1] *Loc. cit.* See also "On the Composition and Origin of the Waters of a Salt-spring in Huel Seton Mine," Phil. Mag. July, 1873.

At this locality I obtained in 1872 a number of interesting crystals of pharmacosiderite, scorodite, and olivenite, which were noticed in the Mineralogical Magazine, vol. i. pp. 16 and 17. I regard this rock as a slightly serpentinized and otherwise much altered hornblende schist.

St. Cleer Downs.—On these downs there are several broad bands of hornblendic rock, mostly lying in the line of strike of the associated slates, and graduating in places into them. The chief mass extends about one mile from east to west, and nearly half a mile from north to south, dipping to the south-south-west. It is usually more or less decomposed, and in a quarry now filled up near the church, asbestos in fine silky fibres was obtained by Canon Rogers in 1818.

Mr. J. A. Phillips gives the first two of the following analyses of this rock : [1]—

	a. Slaty.	*b*. Crystalline.	*c*. Selected.
Water	·63	1·90	7·8
Silica	52·54	47·32	42·2
Alumina	23·83	18·10	7·6
Ferric oxide	2·44	6·21	4·1
Ferrous oxide	4·87	7·72	
Lime	7·89	8·24	3·3
Magnesia	2·67	7·05	33·6
Potash and Soda	5·06	3·80	·7
	99·93	100·34	99·3
Sp. Gr.	2·89	2·90	

c is an analysis of selected portions by myself.

Both *a* and *b* contain free quartz—hence the high percentage of silica. This rock seems to be a partially altered hornblende slate, or else an altered diorite; but the serpentinous change has not proceeded very far. I have often seen thin films of serpentine in the joints, and by breaking up masses of the more highly altered portions of the rock, and selecting the more serpentinous grains, I have obtained a substance with the composition given in *c*. The relative proportions of silica, magnesia, and water in this are pretty near what they are in pure serpentine, if we consider that it was impossible to completely separate all the crystals and grains of magnetite, fibres of asbestos, crystals and grains of unaltered or partially altered augite, felspar, hornblende, etc. The approximation is indeed remarkable if we compare the analyses given of the general rock-masses.

Under the microscope, using a low power, it seems to be composed of a green fibrous granular ground-mass, filled with distinct fibres of asbestos; the ground-mass is very slightly dichroic, and includes some crystals and grains of magnetite, with some irregular masses having ill-defined and shadowy boundaries, which I think are highly altered augite. Using the $\frac{1}{4}''$ power, the ground-mass is resolved almost completely into a network of fibres, while the magnetite appears as a congeries of *rounded* grains. In some instances hornblende crystals are seen, which appear to be changing very slightly

[1] Quart. Journ. Geol. Soc. 1878, vol. xxxiv. p. 487.

into asbestos. The following is an analysis of some of the larger asbestos fibres carefully separated :—

Silica	45·22
Alumina and a little Ferric oxide	30·09
Lime	8·00
Magnesia	10·19
Potash	1·12
Water	5·20
	99·82

Tregerla.—This rock, which occurs in the neighbouring parish (Menheniot), and under very similar conditions, much resembles the preceding.

Cataclense.—This is a somewhat altered dolerite which has been extensively used in North Cornwall for the ornamentation of ancient pulpits, fonts, etc.; and the interesting tomb of Prior Vivian in Bodmin church, which has been so well described and illustrated by the Rev. W. Jago in the "Journal of the Royal Institution of Cornwall," is made of it. It is only slightly serpentinous, yet the change is distinct, especially near the joints, and in the less compact masses. It is often mistaken for Polyfant stone,[1] but it is much harder. The following are analyses of the rock,—1, of an ordinary mass; 2, of a fragment specially selected as being more highly altered than usual :—

	1	2
Silica	45·96	40·8
Alumina	15·02	10·2
Ferrous oxide	6·33	4·5
Ferric oxide	8·03	12·2
Lime	6·37	5·0
Magnesia	18·44	23·5
Water	·22	5·4
	100·37	101·6

Here in 1 serpentinous change is hardly if at all recognizable, while in 2 serpentinous matter exists to a very considerable extent.

Altered eruptive rocks exhibiting serpentinous change occur in a great many other localities in North Cornwall, and especially at Cant Hill near St. Minver. My acquaintance with the rocks of this district dates from the year 1871, and I can quite confirm the observations made by Mr. F. Rutley in his paper.[2] He gives the following examples from this locality :—

No. 1. East end, at top of hill—"bands and small knots of felsitic matter (microcrystalline), separated by bands of translucent greenish-yellow or brownish-yellow serpentine," also "a thin vein of greenish-yellow to brownish-yellow serpentine which is traversed by opaque rust-coloured strings," the bands and the vein being continuous. We seem here as in many other instances to have evidence at once

[1] See Geol. Mag. Dec. III. Vol. III. 1886, p. 365.

[2] Eruptive Rocks from the Neighbourhood of St. Minver," by F. Rutley, F.G.S., Quart. Journ. Geol. Soc. 1886, vol. xlii.

of "segregation" and of "selective metamorphism" in one and the same slide, the result in each case being serpentine.[1]

No. 2, same locality. Here the serpentine is associated with chalcedony and "a yellowish-white matter, apparently kaolin."

No. 4, same hill, west end. Here there is "a large proportion of serpentinous matter; so large, indeed, that by burnishing a smoothly-cut surface of the rock with an ivory paper-knife, a fairly good polish can be communicated to it. When we examine a section of this rock under the microscope, we find some of the original glassy basis has to a large extent been converted into serpentine, especially along lines which seem to indicate fluxion-structure. There is in addition to the serpentine a large proportion of kaolin present."

Nos. 5 and 6, east side, foot of hill. These also contain a very considerable admixture of serpentine; and the author concludes—"There seems then no doubt that the upper portion of Cant Hill, which has been mapped as 'Greenstone,' is really composed of a basic lava of a once vitreous character, but so altered that its original mineral constitution cannot be inferred with precision."[2] Mr. Rutley goes on to speak of the occurrence of serpentine in other eruptive rocks in the locality, and especially at Carlion near Cant Farm.

The occurrence of kaolin in Nos. 2 and 4 connects them with the Duporth rock already referred to,[3] where also very extensive kaolinization of felspathic matter has taken place.

IV. Examples from Devonshire.

Greston Bridge.—The serpentinous rock of this locality is figured (No. 27) and described by Mr. Rutley in his excellent account of the eruptive rocks of Brent Tor, which is published at a prohibitive price by Her Majesty's Stationery Office. It is very incompletely serpentinized, and no analysis has been published or made so far as I know. A similar rock exists at Dunterton.

Anstey's Cove, near Torquay.—This is a coarsely crystalline rock of a dark green colour, and consists of augite, small prisms of triclinic felspar, apatite and magnetite. Some of the augite is but slightly altered; there is a little pale-green serpentine disseminated throughout the mass.[4] In some parts it is very largely serpentinous, much more so than the specimens which Mr. Allport describes would appear to be. The rock occurs distinctly as a dyke cutting through Devonian rocks. No analysis of the rock has been made to my knowledge.

[1] In a note Mr. Rutley says: "Prof. Bonney, who favoured me with an opinion upon these sections, regards much of the substance which I have here called serpentine as a palagonitic material." But palagonite is a constituent of recent volcanic tufa, and hardly likely to be found in so old a rock as this. Moreover, it is fusible, while this mineral, like serpentine, is very infusible. Further, Mr. Rutley says the serpentinous matter has a hardness of 3 or slightly less, while the hardness of palagonite is from 4 to 5.—J. H. C.

[2] *Op. cit.* p. 397.

[3] See Geol. Mag. August, 1886, p. 362.

[4] Allport, "Metamorphic Rocks surrounding the Land's End Mass of Granite," Quart. Journ. Geol. Soc. 1876, vol. xxxii. p. 423.

Babbacombe Bay.—This, like the last, is intrusive in Devonian rocks. "There are here two principal varieties of dolerite—one rather fine-grained and of a uniform grey colour; the other of a lighter shade and porphyritic texture, having conspicuous crystals of felspar scattered through it. Both varieties are highly altered; the secondary products are serpentine and calcite."[1] Much of the original augite of this rock seems to have been converted into hornblende, as in cases already mentioned. No analysis of the rock has been made.

Serpentinous change has been observed in a great many other localities within the two western counties, but probably these will suffice as illustrations.

The methods of the changes which have taken place in these various rocks have been already adverted to (Geol. Mag. 1885, Dec. III. Vol. II. pp. 298–302). It would occupy too much space to discuss these changes completely, as the inquiry is complicated by the great diversity of composition indicated by the various analyses. In comparing these, the very variable amount of iron in its two states of oxidation, of alumina, and of lime, arising from the presence of included crystals and grains of various substances, cannot fail to be noticed; and of course these greatly varying proportions affect those of the water and silica, and especially those of the magnesia. The diversity of composition, however, is more apparent than real, and is owing in some instances to the irregularly porphyritic character of the original rock, and in others to subsequent infiltration and crystallization. Thus the alumina may be generally traced to the presence of still undecomposed crystals of felspar, or else to kaolin resulting from such; to augite, or hornblende; the iron to magnetite or to flocculent masses of peroxide of iron; and the lime either to felspar or else to patches or veins of calcite. Take away these, and the serpentinous ground-mass will often be found to consist of nearly pure serpentine.

Conclusion.

I have thus shown that serpentinous change is extensively met with in both stratified and intrusive rocks in many parts of the two western counties of England. The rocks sometimes change as a whole—as at Botallack and Clicker Tor—or in certain of their foliæ—as at Cant Hill—or thin films of serpentine are produced, bounding the numerous joints which divide the rock into angular fragments, still purer serpentine, with or without asbestiform matter, being deposited wherever the joints are sufficiently open—as at Terras. Crystals of augite, olivite and hornblende all appear to have been frequently changed into serpentine—with or without intermediate changes—while felspar crystals, if present, are either converted into saussurite, or else are more or less completely kaolinized. In the case of the hornblende crystals, the change begins by loss of dichroism. Then, as in the case of augite also, the crystal breaks up into a fibrous mass of acicular crystals; and finally amorphous

[1] Allport, *ibid.*

serpentine without trace of fibrous structure is produced. The next stage is a general hydration of the whole ground-mass, the disappearance of alumina from its composition, and the oxidation of magnetite into peroxide of iron.

Such changes are analogous to those observed by Prof. Heddle in the serpentinous marbles of Tyree, Lewis, and other places in the North of Scotland, where *augite* has been converted into serpentine; as well as in the *picrolite* of Balta and the *crysotile* of Fetlar, where forms of *hornblende* have been so changed; it is very similar to that which he observed at Beauty Hill near Aberdeen, where waxy *labradorite* (a mineral closely resembling the felspathic component of the Porthalla stone) "*is seen to pass within a space of about an inch into this mineral*" (an aluminous serpentine or pseudophite) "*by insensible gradation.*" The italics are all the Professor's. For the full discussion of the processes of change in these different circumstances, which to me is perfectly conclusive, I must refer to the original paper in the Proceedings of the Royal Society of Edinburgh. On the whole, it seems to me that serpentinous change in hornblendic and augitic substances is little less common than the kaolinization of felspar; and these two modes of metamorphism are not unfrequently to be seen in the same rock-mass, as at Duporth (see Min. Mag. vol. i.), Cant Hill (see *supra*), and many other places.

REVIEWS.

I.—Die Versteinerungen des Cambrischen Schichtensystems der Insel Sardinien, nebst vergleichenden Untersuchungen über analoge Vorkommnisse aus andern Ländern. Von Dr. J. Georg Bornemann, M.A.N. Erste Abtheilung. Mit 33 Tafeln, No. i.—xxxiii. Nova Acta der Ksl. Leop.-Carol. Deutschen Akademie der Naturforscher. Band LI. No. 1. (Halle, 1886.)

The Fossils of the Cambrian Strata of the Island of Sardinia, with a Comparative Study of similar forms from other Countries. By Dr. J. G. Bornemann. 1st part, 4to. pp. 83, and 33 plates.

THE present is the first portion of a work in which the author proposes to give a complete description of the fossils from the Cambrian strata of Sardinia, which he has collected during successive visits to the island. Owing to the extremely complex manner in which the strata have been disturbed, it has not been possible to make out in detail the succession of the beds; but the oldest fossiliferous rocks near Canalgrande on the west coast of the island, consist of a series of clay-schists, rich in Trilobites, quartzitic sandstones with sponge (?) remains, and dark crystalline, and in part oolitic, limestones. These are succeeded by a great thickness of massive limestones, followed by successive alternations of shales with *Lingula*, sandstones with Trilobites, and limestones containing large numbers of the peculiar Coral-like fossils known generally as *Archæocyathus*. Associated with these Coral (?) bearing limestones and marbles are coarse sandstones filled with *Cruziana*.

The Trilobites of the lower zones are stated by the author to present a general resemblance to *Paradoxides* and *Olenus*, though for the most part they are specifically and even generically distinct from any forms yet described; in a somewhat higher zone examples of *Illænus* are associated with survivors of the older forms.

The description of the Trilobites is, however, reserved for another part: the fossils treated in the present one are ranged under the heads of Plantæ, Spongiæ and Archæocyathinæ. The forms described as plants are, at the best, doubtful. Thus the author, accepting the views of Lebesconte, de Saporta, and Delgado, places *Cruziana* as a genus of Algæ. In Sardinia, as elsewhere, there is not a trace of organic structure in these fossils, and there is nothing to controvert the striking arguments of Nathorst (whose name is not even mentioned by the author) that they are most probably tracks or impressions.

A new genus, *Phytocalyx*, is proposed for conical or hemispherical bodies, which weather out of a sandstone rock in considerable abundance. No structure whatever is preserved. They are regarded as Algæ analogous to Fucoids or Siphoneæ; but, judging from the description and figures, it seems to be equally as probable that they may be inorganic concretionary bodies or infilled casts of hollows made by burrowing organisms.

Another new genus, *Epiphyton*, is stated to consist of fan-shaped groups of cells which are regarded as formed by a lime-secreting Alga allied to the Siphoneæ.

Another form, growing in small rounded masses, like Nullipores, and consisting of an agglomeration of minute curved tubes, is extremely abundant, forming in places whole beds of rock. The author regards it as a new genus of calcareous Alga, and finds a resemblance in the form, arrangement, and dimensions of this Cambrian marine fossil to a species of existing Alga which grows on the surface of calcareous rocks in Switzerland. Some of these land-Algæ also secrete lime, and form hard stony crusts, and the author thinks there is reasonable ground for placing the fossil in the same group with the recent form!

We may here point out the fact, that this genus, which the author names *Siphonema*, is by no means new, as he supposes, since it was clearly described, and the typical form figured, by Nicholson and Etheridge, jun., nine years since, in their Monograph of the Silurian Fossils of Girvan, under the name of *Girvanella* (*l.c.* p. 23, pl. ix. fig. 24). As the writer has had the opportunity of seeing both the specimen described by Dr. Bornemann, as well as that which has received the name of *Girvanella*, he can confidently state that they are generically identical.

Singularly enough, the same fossil occurs at a similar geological horizon in the United States, and it has lately been described by Prof. H. M. Seeley as a genus of free calcareous sponges under the name of *Strephochetus* (American Journal of Science, vol. xxx. 1885, p. 355). Thus for this same fossil we have the following references:—

1878. *Girvanella*, Nicholson and Eth. jun. Probably Rhizopods.
1885. *Strephochetus*, H. M. Seeley. Calcareous Sponges.
1886. *Siphonema*, Bornemann. Algæ allied to living subaerial forms.

Whatever may be said in favour of the alliance of this genus to Rhizopods, on which the writer is not competent to pronounce an opinion, it is quite certain that it has not the least resemblance to Calcisponges, and its affinity to living subaerial Algæ seems very problematical. It is clear, however, that these bodies should retain the generic name first applied to them, and the two later names must be suppressed.

In the class Spongiæ the author proposes a new genus, *Palæospongia*, to include small cylindrical branching bodies, from 1 to 5 mm. in thickness, which in places fill beds of slaty rock, and are exposed in relief on their weathered surfaces. These forms now consist, for the most part, of angular quartz grains; but it is stated that, in microscopic sections, siliceous spicules arranged parallel with each other to form fibres can be distinctly seen, and between the spicules are grey and dark lines, regarded by the author as indications of the keratose materials of the organism, by which, when in the living state, the spicules were held together! The genus is regarded as allied to existing monactinellid sponges, and a photograph of a section of the existing *Axinella polypodioides* is given to show the resemblance between it and sections of these Cambrian fossils! We must confess our inability to perceive this asserted likeness, and we think that the few, scattered, crooked linear bodies shown in the figure, which the author supposes to be spicules, may be otherwise explained. It would indeed be a striking fact, if sponges of this character, which, owing to the fact that their component spicules are only held together by perishable horny material, are of extremely rare occurrence in newer undisturbed strata, should in these disturbed Cambrian rocks be preserved in great abundance.

The author further states that the forms described by Billings as marine plants, under the name of *Palæophycus*, have a remarkable resemblance to his *Palæospongia*. In our own opinion the forms known as *Palæophycus*, Bill., are most probably the infilled tracks and burrows of marine organisms, and we think that *Palæospongia* may have a similar origin. It is to be hoped that, to clear up, if possible, the doubts as to the real nature of this genus, the author will submit his specimens to some one acquainted with the characters of fossil sponges.

The peculiar cylindrical, cup- or funnel-shaped fossils, of which the genus *Archæocyathus*, Billings, may be taken as the type, are placed by the author as a distinct class of Cœlenterates, in proximity to Sponges, Anthozoa, and the Medusoid Polyps. Fossils of this group are present in great abundance in the massive Cambrian Limestones of Sardinia, but they are, for the most part, not well preserved, and can only be studied in microscopic sections. Of these the author prepared a large series, and photographs of them are given in the accompanying plates.

In addition to *Archæocyathus*, Bill., the author proposes two new genera, *Coscinocyathus* and *Anthomorpha*. In the former, regular

transverse tabulæ are present, as well as the vertical lamellæ, whilst in the latter, the transverse structures are irregular. Associated with the ordinary forms of *Archæocyathus*, a peculiar fossil, consisting of anastomosing, apparently homogeneous fibres, frequently occurs. It is believed by the author to be the vegetative state of development from which the complete cups of *Archæocyathus* originate, and thus to indicate a true alternation of generations in these Cambrian fossils! To this form, though not regarded as an independent genus, the name *Protopharetra* is given.

An equally surprising statement is, that delicate threads or fibres of calcite present in the interspaces of the walls of some examples of *Archæocyathus* and *Coscinocyathus* are the fossilized remains of such soft organic structures as sarcode-threads, muscle-fibres and tentacles. The author thinks it possible that these structures may have been inclosed by the ooze, and then replaced by calcite!

Though the author has described in detail numerous species, it can hardly be said that our knowledge of the true nature and affinities of *Archæocyathus* and its allies has been increased. The author doubts the correctness of the observation of Billings as to the spicular nature of the walls of *Archæocyathus*, and thinks that the spicules figured were accidental intrusions.

Though we regret our inability to accept most of the determinations and conclusions of the author, we nevertheless readily admit the value of the work which he has done in bringing to light and describing the organisms in these unpromising Cambrian rocks of Sardinia. It is of great interest to know that many of the forms are closely similar to those recorded by Billings from the so-called Calciferous rocks of the Mingan Islands and other localities bordering the St. Lawrence, and this similarity will probably be further shown when the Trilobites and other fossils are described. It may also be mentioned that this work has a direct bearing on questions connected with British geology, since *Archæocyathus* has lately been discovered by members of the Geological Survey of Scotland in the Durness limestones. The specimens, though not uncommon, are but fragmentary and in a poor state of preservation; but, in spite of this, Mr. B. N. Peach, F.G.S., has been able to ascertain from them some important conclusions respecting the relations of *Archæocyathus* to *Calathium*, Bill., which it is hoped will soon be published.

G. J. Hinde.

II.—The Origin of Mountain Ranges. By T. Mellard Reade, C.E., F.G.S., F.R.I.B.A. (London, Taylor & Francis, 1886.)

THIS is a handsome octavo volume of 359 pages, profusely illustrated with forty-two full-page or folding lithographic plates. The short final chapter contains the author's main conclusions; and these are further condensed into its first two sentences. "Mountain-ranges are ridgings-up of the Earth's crust, which take place only in areas of great sedimentation. The exciting cause of the various horizontal and vertical strains, ending in the birth of a

mountain-chain, is the rise of the isogeotherms, and consequent increase of temperature" [and expansion] "of the new sedimentaries, and that portion of the old crust that they overlie" (p. 326). It will therefore be seen that the theory is founded on what has been termed the Herschel-Babbage hypothesis, that, where thick deposits are laid down, the rise of the isogeotherms into them must needs cause their expansion; coupled with the observation of American geologists, that in general a mountain-range occupies an area where sedimentation has gone on undisturbed, until the deposit has attained a great thickness, and that the event, next in sequence there, has been the elevation of that very tract into a mountain-range. The Americans have attributed this subsequent elevation to the contraction of the Earth's volume through secular cooling, acting upon the newly-deposited matter as a weak place. But Mr. Reade rejects this supposition. In this rejection I agree with him. I think the question may be put simply thus. If any mass contracts equably in all its parts, the rate of shortening of every dimension must be the same. If then the whole Earth had cooled down to the present temperature of the surface, every dimension would have contracted equably, and there would be formed neither wrinkles nor cracks. But in fact the crust has cooled more than the interior. Therefore the circumference of the crust must have contracted in a greater ratio than the radius of the nucleus, which it envelopes. Its tendency would therefore be to crack; and, although the weight of its parts might close up the cracks as they tended to be formed, still no compression would take place, unless we throw more than its proper share of cubical contraction into the vertical dimension.[1] It does not seem that this conclusion will be much affected by the condition of the interior, whether it be solid or liquid.[2]

Accepting the theory of a solid globe, and the view, that the matter of which it consists becomes fluid on the pressure being reduced, the author thinks that this matter is subject to local fluctuations of temperature, a property which it is not easy to reconcile with solidity. Rocks at a depth of two miles and over, whether originally soft mud or clay, may be treated as solid matter. "Solid by compression, but ready to flow, one way or other, as the pressure may be reduced or increased"[3]—a very accommodating condition, but difficult to understand, because, if solid only by compression, one would imagine that *increased* pressure would make them more obstinate to move.

There seems a difficulty in accounting for the accumulation of

[1] In a paper upon the subject, which I have lately contributed to the Phil. Mag. (Feb. 1887), I have thrown the whole contraction into the vertical, a supposition, as I have expressed it, "too highly favourable."

[2] In considering the possible causes of contraction of the nucleus, perhaps enough has not been made of the evisceration of the interior by volcanic action of various kinds. How much must have been vomited forth to form the great basaltic flows—and the pumice-covered floor of the deep oceans—and the dust clouds, which must often and often in geological ages, for months and years at a time, have covered the sky all round the globe!

[3] p. 91.

thick deposits on the theory of a solid globe. They cannot make a cavity for themselves, because the increase of pressure due to their weight would increase the rigidity of the sea-bed. The cavity must therefore somehow be already hollowed out, and it must conveniently border a continent, to be within reach of the sediment. This is a point which needs to be explained. But suppose that done; and conceive the sediment to be in process of accumulation. A second difficulty presents itself. Mr. Reade appears to consider that the hollow would be first filled up, and that the heat would subsequently be conducted from below into the sediments, and that they would swell up into a mountain region. But as a fact the heat would enter them concurrently with their deposition, so that the swelling up would begin at once. When the top of the deposit had reached the sea-level, deposition must cease; and it would be only the balance of heat remaining to be made up after that time, which could be effective towards raising the deposits above the sea-level. If deposition was a rapid process, the larger part of the heat might remain still due, and therefore available to raise the tract above the sea-level. But it is a very slow process—so slow that Mr. Reade thinks forty-two millions of years not too long for the deposition of the matter from the Carboniferous upwards in Western North America. Surely in that time the sediments would be almost quite warmed up before they got above the sea-level.

A valuable part of Mr. Reade's work consists of the experiments he has made upon the rates of expansion of different kinds of rock. His results agree closely with those obtained by Mr. Adie long ago; giving, as he puts it, 2·77 feet per mile per 100° Fah. He has not referred to Mallet's experiments upon molten slag, of which I have given an account in my "Physics of the Earth's Crust."[1] It is satisfactory to learn that, even at the high temperatures examined by Mallet, the coefficient of expansion keeps fairly near that determined by Adie, and now by Mr. Reade, for lower temperatures. Applying his result to masses of the size contemplated, the linear expansion of 1000 miles raised 1000° Fah. (which he takes as the mean increase of temperature for the new deposits and of the old crust under them) would be about $5\frac{1}{2}$ miles. At p. 158 he assumes a lenticular mass, measuring 1000×500 miles, and 20 miles deep in its thickest part, raised to a mean of 1000° F. above its previous temperature. Lying in a rigid dish of crust, the entire cubical expansion would be effective to elevate the surface. The lower strata, being heated more than the upper, expand more, and become crumpled, because their periphery is confined by the rigid crust. They then burst up the superincumbent less-expanded beds, which gape at the anticlinals. Into these the lower heated rocks are intruded, and form plutonic cores. The interstitial differential movements give rise to foliation, and similar phenomena; and in places the hot solid rock beneath, finding weak places, and "struggling" to escape, intrudes itself into dykes, and becoming more and more liquid as it reaches regions of less and less pressure, at last appears at the

[1] p. 68, note.

surface in volcanic manifestations. Such is an outline, as I understand it, of the theory.

If the two preliminary difficulties can be disposed of, the theory seems well suited to explain the formation of elevated plateaux. But for producing the intense corrugation, which characterizes most mountain ranges, the amount of horizontal expansion which it affords appears inadequate; especially when we consider, that much of the compression would be expended in deforming the material upwards, without rotation of the parts. The scale is made appreciable if one takes a metre rule, and compares five millimetres with the entire length—or a yard measure with less than a quarter of an inch. The corrugation arising from compression on such a scale must be very small. Many of the numerous and interesting sketches given from nature make one feel rather the inadequacy of the theory to account for the disturbances shown. Altogether this part of the theory needs more reasoning out quantitatively.

Chapter xxi. on the connection of volcanic action with mountain-building, is worth studying. The subject is an obscure one, but it is so intimately connected with every manifestation of force in the Earth's crust, as cause with effect, that they cannot be separated. Mr. Reade's leading idea seems to be, that the reservoir of magma is solid, but that it exerts expansive stress to find escape. Being solid, it does not transmit liquid pressure from one vent to another; so that lava can stand at different levels in them.

The experiment represented in figs. 1 and 2 of plate xlii. and the description of it (p. 431) are interesting. Several strips of paper were laid upon each other, and lines were drawn across the edge of the block so formed. It was then bent into folds. The inclination assumed by the lines now indicated the manner in which the strips had slidden longitudinally over one another in the process of folding. I may mention that the position taken by these cross lines exactly agrees with that of the "planes of less perfect cleavage" in Mr. Sorby's well-known diagram of a contorted bed in slate rock at Ilfracombe.[1] This shows that the cleavage follows the lines of distortion, not those of shear; for the latter would, in the experiment, have been along the surfaces of the sheets of paper.[2]

Mr. Reade, in plate xxxviii., gives a good demonstration of the extension that necessarily accompanies the compression of strata into close chevron folds, which, from what has been said in the preceding paragraph, would lead one to expect such folds to be in general affected by cleavage inclined at an angle across them.

There is throughout the book a certain want of precision in scientific language. "Heat" is sometimes used where the word should be "temperature"; "strain" where it should be "stress." At p. 303, having been told that mechanical denudation from the Mississippi basin is one foot in 6000 years, we read, "If we add the

[1] Edin. New Phil. Journ. vol. lv. p. 138, 1853; and Lyell's Students' Elements, p. 577; also Prestwich's Geology, vol. i. p. 264.

[2] Rev. O. Fisher on Cleavage and Distortion, GEOL. MAG. Decade III. Vol. I. p. 400, line 5, 1884.

matters removed in solution, I have shown that we must reduce the time to one foot in 4500 years." To take notice of a verbal slip, confounding time with feet-per-year, may be making a mountain of a molehill. If I have done that, at any rate I have achieved a success in mountain-building.

In chapter x. our author gives very good reasons for considering the globe to contain a sufficient supply of heat for all the purposes of his theory. But he has made a mistake in supposing (as by working out his figures he seems to have done) that, if the temperature of the whole were reduced to zero Fah., all its heat would be exhausted. To accomplish that result, it would need to be reduced 460° Fah. lower still. O. Fisher.

REPORTS AND PROCEEDINGS.

Geological Society of London.

I.—March 9, 1887.—Professor J. W. Judd, F.R.S., President, in the Chair.—The following communications were read:—

1. "On *Chondrosteus acipenseroides*, Ag." By James W. Davis, Esq., F.G.S.

Sir P. Egerton described two species of *Chondrosteus* from the Lias of Lyme Regis, viz. *C. acipenseroides*, Ag., and *C. crassior*, Eg. The author describes an unusually fine specimen from the same locality, 44 inches long, the head, trunk, and tail being exceptionally complete, whilst a considerable portion of the elements of the vertebral column is preserved.

The head is proportionately large and deeper than the body of the fish. It has an almost circular outline with a diameter of about 9 inches, but the snout has been broken off during extraction. The cranium was protected by dermal bones or scutes. The anterior portion of the head, beneath the orbit, does not exhibit any traces of external defence, thus differing from existing Sturgeons. The frontals, postfrontals, parietals, mastoid, and some of the occipital plates are present: all these bones are united by sutures. The external surface of the dermal plates is coarsely striated or ridged; the ridges radiate for the most part from the centre towards the margin, the surface being covered by strips of ganoine. The orbit is oval. The base of the skull is formed by bones more completely ossified than in the existing Sturgeons: these are more extensive than in the Teleostean fishes, being the equivalents of the sphenoid bones of the latter. Sir P. Egerton, in his description of the genus *Chondrosteus*, states that the elements of the scapular arch, which in recent Sturgeons are three in number, are reduced to two in the fossil genus by the coalescence of the scapula and the coracoid. The author describes it as composed of a series of three bones, suprascapula, scapula, and coracoid (or clavicula). The last is united with the pectoral fin by two bones, apparently representing the radius and ulna of Owen (coracoid and scapula of Parker). The pectoral fin is large and comprised forty-two rays. The mandibles and maxillaries are large and well ossified, in this respect differing

from existing species; there is no evidence of teeth. From the position of the respective maxillary and premaxillary bones in this specimen there can be no further doubt that the small bifurcated bone of *C. acipenseroides*, Ag., described as the maxillary bone, is really the premaxillary.

Bony neurapophyses are preserved in the anterior portion of the body. There is no trace of the vertebral column nor of ribs or hæmapophyses, except in the caudal fin, where hæmapophyses support the lower lobe. The neurapophyses extend from the occipital region of the skull to the base of the dorsal fin, 13 inches. In this length there are preserved thirty-five neurapophyses, representing the same number of vertebræ. The first ray of the dorsal fin is inserted above the thirtieth vertebra; the total number of vertebræ in the spinal column would be from eighty to eighty-five. The caudal fin is very large and was a powerful organ of propulsion; its upper lobe, as in the recent Sturgeon, is the longer of the two.

The specimen is nearly twice the length of those described by Egerton, and the author indicates the differences in some detail. The division of the scapular arch into three parts, the suprascapula, the scapula, and the coracoid, appears to be undoubted, whilst in the specimens previously described the scapula and coracoid are said to be united. The two latter ossifications of the shoulder-girdle are separate in the existing Sturgeons, and in the Ganoid fishes this is also generally the case.

The author then refers to the opinion expressed by Sir P Egerton as to the homology of the cranial plates of fossil Sturgeons when compared with recent ones and also with Teleosteans, and to the confirmation of these views by Prof. Parker, who concludes that, although the Sturgeons cannot be said to occupy an intermediate position directly between the Selachians and the Bony Ganoids, yet on the whole that is their position.

Lastly, the author states his belief that there is no specific difference between *C. acipenseroides*, Agassiz, and *C. crassior*, Egerton.

2. "On *Aristosuchus pusillus*, Ow., being further Notes on the Fossils described by Sir R. Owen as *Poikilopleuron pusillus*, Ow." By Prof. H. G. Seeley, F.R.S., F.G.S.

A Wealden fossil, comprising certain dorsal, sacral and caudal vertebræ, with some associated bones belonging to the pubic region, formerly in the collection of the Rev. W. Darwin Fox, but now in the British Museum, was described by Sir R. Owen in 1876 as *Poikilopleuron pusillus*. In the present paper the author showed that the presence of a peculiarly-shaped medullary cavity in certain vertebræ, a character upon the strength of which the bones were referred to *Poikilopleuron*, Desl., was not peculiar to that genus, but had been found in *Megalosaurus* and in other Dinosaurian reptiles, whilst the characters of the sacrum in "*Poikilopleuron pusillus*" differed from those of any Crocodilia. The species was clearly not a *Poikilopleuron*, but was apparently a Dinosaur belonging to an undescribed genus, for which the name of *Aristosuchus* was proposed.

The pubic bones were described and shown to resemble those noticed by Prof. March in *Allosaurus*, *Ceratosaurus*, and *Cœlurus*, and

the specimen itself has been referred by Prof. Marsh to the last-named genus. The genera named were, however, placed in distinct Dinosaurian suborders, and consequently it was evident that the pubic bones by themselves were insufficient for generic determination, whilst the dorsal vertebra of the Wealden fossil had the texture usually found in Dinosauria, and not that peculiar to *Cœlurus*. The mode of attachment of the ribs was also different. The sacrum of *Cœlurus* was unknown, but was probably very different from that of *Aristosuchus*. In the latter the transverse processes or sacral ribs were given off from each individual vertebra, as in certain American forms, and not as in *Iguanodon*, *Hylæosaurus*, *Megalosaurus*, etc., from the junction between two centra.

The five sacral vertebræ of the fossil and their apophyses were then separately described in detail, and also an associated fragmentary caudal vertebra; and the conclusion was expressed that *Aristosuchus* was a Dinosaur nearly related to certain imperfectly-described American types, such as *Allosaurus*.

3. "On *Patricosaurus merocratus*, a Lizard from the Cambridge Greensand, preserved in the Woodwardian Museum of the University of Cambridge." By Prof. H. G. Seeley, F.R.S., F.G.S.

No Lacertilian has hitherto been described from the Cambridge Greensand. The only remains of Lizards known to the author as having been derived from that bed consisted of the two bones now described, the proximal end of a femur, and a sacral vertebra with the processes broken away. The former exceeded in size the corresponding bone of the largest living Monitor, and differed from the femora in all recent Lizards in so many respects as to indicate subordinal distinction. The vertebra was not found with the femur, and may have belonged to a different species; but there being nothing in the characteristics of the two bones inconsistent with their having belonged to one specific type, both were fully described as types of a new genus and species.

4. "On *Heterosuchus valdensis*, Seeley, a procœlian Crocodile from the Hastings Sands of Hastings." By Prof. H. G. Seeley, F.R.S., F.G.S.

An ironstone nodule from the Hastings Sands was acquired by the British Museum from Dr. Mantell's collection. The specimen measured 10 centimètres by 6, and displayed on its water-worn surface several procœlian vertebræ of a small Crocodilian, together with some other bones, perhaps belonging to a different reptile. These other bones appeared to comprise portions of a skull with peculiarities not hitherto recognized in procœlian Crocodiles, and a pubis and ischium exhibiting distinct Lacertilian characters, and of comparatively very small size, but still situated in proximity to the sacral vertebræ.

The vertebræ were described in detail in the paper, and referred to a new genus and species. They included one late cervical vertebra, eight dorsal, and two which might be considered as sacral. All appeared to be mature, and were more completely ossified than the same bones in living Crocodiles. The body of each centrum was compressed laterally, the neural arch comparatively depressed and thrown out laterally above by the inferior V-shaped approximation

of the side of the centrum. Several other peculiarities were also pointed out.

The paper concluded with notes on other vertebræ of similar character from Tilgate and Brook, and attention was called to a Crocodilian cervical vertebra with the procœlian cup from the Purbeck beds.

5. "On a Sacrum, apparently indicating a new type of Bird (*Ornithodesmus cluniculus*, Seeley), from the Wealden of Brook." By Prof. H. G. Seeley, F.R.S., F.G.S.

After some remarks on the characters of the sacrum in Birds, Ornithosauria, and Dinosauria, the author proceeded to describe a sacrum composed of six vertebræ in the Fox collection, now at the British Museum, and then to compare the fossil with the corresponding bones of the three groups named. The resemblance to the Dinosaurian and Ornithosaurian sacral vertebræ was less than those which connected the fossil with birds. From the latter it was distinguished by the smaller number of vertebræ in the sacrum, the absence of sacral recesses for the lobes of the kidneys, and the form of the articular face of the first sacral vertebra. But the small number of sacral vertebræ in *Archæopteryx*, the want of renal recesses in *Ichthyornis*, and the characters of the articulation in the Solan Goose showed that these differences were not essential; and the author concluded that the fossil belonged to a true Bird, but that it formed a link with lower forms, and approximated more to Dinosaurs than did any other Avian type hitherto described.

II.—March 23, 1887.—Prof. J. W. Judd, F.R.S., President, in the Chair.—The following communications were read:—

1. "Notes on the Structures and Relations of some of the older Rocks of Brittany." By T. G. Bonney, D.Sc., LL.D., F.R.S., Professor of Geology in University College, London, and Fellow of St. John's College, Cambridge.

These notes are the results of a visit to some of the more interesting geological sections in Brittany, in the autumn of last year. The author is greatly indebted for information to the Rev. E. Hill, who took part in the summer excursion of the Société Géologique de France, and to Dr. Charles Barrois, who has for long been engaged in investigating the geology of Brittany.

(1). The author briefly noticed the glaucophane-amphibolites and the associated schists of the Ile de Groix, which have been already admirably described by Dr. C. Barrois. He considered the evidence to be on the whole in favour of the view that the former were originally igneous rocks intrusive in the latter, but modified by subsequent pressure (the marks of which are very conspicuous in the schists), and by mineral change, which probably produced the glaucophane, the garnets being anterior to the mechanical disturbance.

(2). The next part of the paper treated of sections in the district about Quimperlé. Cases were cited of granite, modified by pressure so as to result in a gneissoid rock, and of banded gneisses also modified by subsequent pressure, but, in the author's opinion, indubitably banded gneisses anterior to the mechanical disturbance, and exhibiting

structures which, in his opinion, lend themselves more readily to a theory of some kind of original stratification of the constituents than to any other. The amphibolites in this region are undoubtedly of igneous origin (intrusive), but subsequently modified. In one part of the district are granitoid gneisses, but little modified by subsequent mechanical action, which in structure differ greatly from the granites, and much resemble the older Archæan gneisses of other regions. A "hälleflinta" to the north of Quimperlé proves to be in part a rhyolitic rock, modified by subsequent pressure; part, however, may be an indurated tuff of similar composition.

(3). In this part of the paper were noticed the crystalline rocks of Roscoff, and (more briefly) the Palæozoic strata about Morlaix, with the mineral and structural modifications due to pressure and to the action of intrusive igneous rocks. The author pointed out that, in the latter case, the results either of pressure-metamorphism or of contact-metamorphism differ much from the crystalline schists, which, both in Brittany and elsewhere, are regarded as of Archæan age; and that here in the north at Roscoff, we have a series of banded gneisses, less modified by subsequent pressure than in the south, the structures of which are very difficult to explain on any theory of a "rolling out" of a complicated association of igneous rocks, but which are such as would naturally result from some kind of stratification of the original constituents.

The result of the author's work is to strengthen the opinion which he has already expressed, that while the structures of some foliated rocks may be regarded as primarily due to pressure operating on suitable materials, the structure of others seems opposed to this explanation. At any rate the latter rocks appear to have assumed a crystalline condition with a semblance of stratification in Pre-Cambrian times; so that, whatever may be their genesis, they are rightly called Archæan gneisses and schists.

2. "The Rocks of Sark, Herm, and Jethou." By Rev. E. Hill, M.A., F.G.S.

The author described the island of Sark, about three miles long by two broad, with the smaller areas of Little Sark and Brecqhou. Little Sark is attached to Great Sark by a narrow ridge (the Coupée), which the weather is rapidly degrading, while Brecqhou is completely separated by a narrow strait. The greater part of these islands consists of dark hornblendic banded rocks, which closely resemble those of the Lizard, and show by their alternation of materials and their phenomena of current-bedding that they have originated by some kind of deposition. These were shown to lie unconformably on a gneiss, seen only at the eastern extremity of the island, in and around the Creux Harbour. Over this the beds lie in a dome, and as they slope away on the N., W., and S., they pass under a highly-crystalline rock, which has been called a metamorphic gneiss. This rock was described, and evidence given to show that it is really a granite,—an igneous rock which has overflowed the hornblendic beds.

Veins and dykes were briefly noticed; they include a dyke of mica-trap. The islands of Herm and Jethou, lying between Guernsey and Sark, were also described. Jethou contains a fine raised beach. They

consist of granite which presents signs of an E. and W. dip. A probability was shown that this granite is part of the mass overlying Sark.

Finally, the age of these rocks was shown to be Archæan, and attention was called to the evidence they give that some at least of the Archæan rocks did not originate out of igneous masses by crush, but were formed by some process which, if not aqueous sedimentation, at all events was some kind of successive deposition.

3. "Quartzite Boulders and Grooves in the Roger Mine at Dukinfield." By James Radcliffe, Esq., F.G.S.

Quartzite boulders have from time to time been found imbedded in the roof of the Roger Mine coal-seam. Similar boulders had previously been described from coal-seams both in Leicestershire and the Forest of Dean. The composition of the Roger-Mine boulders was shown by notes furnished by Prof. Bonney to be quartzose grit and quartzite, containing some grains of felspar, epidote, and tourmaline and flakes of mica. This composition resembled that of some of the pebbles in the Bunter conglomerate of the Midland counties, and also that of some of the Loch Maree quartzites. The boulders varied in weight from 166 pounds to 4 pounds, and appeared to have been dropped into the coal, one boulder having been found standing edgeways. They were half imbedded in the seam, half inclosed in the overlying grey shale.

In the upper surface of the coal in the same mine, grooves were found running about S. 50° E., the mean direction of faults, slips, etc., being S. 26° W. The sides of these grooves were raised, as if by pressure, and each depression commenced as a small groove, then increased in depth and breadth, and finally died out.

CORRESPONDENCE.

INTERGLACIAL LAND AND MAN.

Sir,—As an item of evidence in favour of the existence of an interglacial land surface, so ably maintained by Mr. Jukes-Browne in this Magazine for March, and of the presence of Man in this country at the time, I send an extract out of a letter (Sept. 30, 1861) from the late Dr. Bowerbank to the late Dr. Bree, of Colchester, which has not, I think, been published. The occasion of its being written was that Dr. Bree had shown him the cut deer's horn from Clacton, described by me in the "Geologist," Aug. 1861, and figured in plate ix. "I have in my possession remains of a human skull, that was found mixed with bones of extinct animals at the bottom of a deep dyke on an axis of elevation, covered by the detritus of the Magnesian Limestone to about one-third of the height of the great crack, and the remainder then covered by the Red Drift of Yorkshire; so that it is fair to infer that it was deposited in the crack, or dyke, before the submergence of that country beneath the sea, and again elevated after being covered by the great northern Drift. This would appear to give an immense period to the existence of Man. The finding of these bones are (*sic*) so well authenticated, that there can be no reasonable doubt of their being in every

respect genuine. I have often thought of publishing these facts, and I think I shall do so ere long."

What became of Dr. Bowerbank's collections?

I am quite aware that, as a rule, a geologist will not trust any one to observe correctly except himself. But on questions of this kind, where the evidence is destroyed in the process of being obtained, autopsy is impossible. We are therefore obliged to rely upon cumulative evidence, the weight of which depends upon the circumstance, that it is highly improbable that *every* observation should be erroneous, while at the same time a *single* correct one is sufficient to prove the point at issue.

O. Fisher.

Harlton, Cambridge, *4th April.*

FELSPAR IN THE LIZARD SERPENTINE.

Sir,—May I be permitted to state, as briefly as possible, the reasons why the characters described by my friend Mr. Teall in his letter on "The Lizard Serpentines," fail to convince me that the mineral in question, which occurs in the Rill rock, is really felspar? As he rightly says, the identification of a mineral under the microscope is often more or less a matter of inference. Hence it is occasionally quite possible for two observers, both of some experience, to take different views. I do not then attribute a mistake to him in the ordinary sense of the word, nor wish in any degree to detract from the value of his work. The point is one of considerable interest, where there is ample room for two opinions.

To prevent any misunderstanding, let me say that I do not in the least deny that felspar may occur as an accidental constituent in a peridotite, and, if it occurred anywhere in the Lizard Serpentines, I should expect it, as will be seen from my remarks on that of Gue Graze, in the serpentine of the Kynance-Mullion district.[1] The difficulty of determining this particular mineral is not a new one to me, as I had to consider it nine years ago when preparing the above-named paper.

The following are my reasons, so far as they can be expressed on paper:—

1. The texture and aspect of the mineral in question, seen under the microscope, do not appear to me exactly identical with those of a felspar, but remind me rather of a pyroxenic mineral.

2. The brown earthy decomposition of the mineral seems to differ slightly from that of a felspar, and I find a similar decomposition in some grains of decomposing hornblende (mineral identified by cleavage and extinction) in the serpentine of Lower Pradanac, also in that of Mullion and Helston Road. I have also seen a similar decomposition in bastite or enstatite.

3. As to the tints seen between crossed Nicols. Low neutral tints are not rare in enstatites. I have noted them in augites, when somewhat decomposed, and in certain hornblendes. In my slides from Lower Pradanac the hornblende generally shows chromatic polarization, but some grains exhibit these low neutral tints. I believe it indicates incipient decomposition. As we have lately heard much

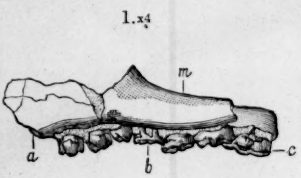
[1] Quart. Journ. Geol. Soc. vol. xxxiii. p. 918.

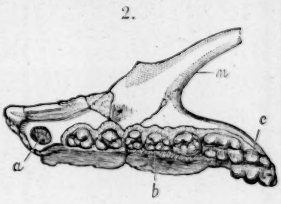
about the life of minerals, we may say that the flush of health is being replaced by the pallor of approaching death.

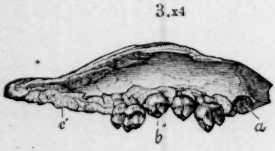
4. As regards the twinning, which is no doubt a very strong argument, I find a rather similar lamellar twinning (as it appears) in hornblende (serpentine of Mullion and Lower Pradanac). These seem to be produced by the formation of a mineral (doubly refracting but with different extinction) along the cleavage planes parallel to ∞ P, but I am by no means sure that this is the explanation of every case. In my slide (of 1878) from the Rill it occurs in a mineral which much more resembles a variety of enstatite than felspar. In the slide cut from Mr. Teall's specimen the twinning both lamellar and in two directions at high angles occurs in minerals which I cannot distinguish from the low-tinted pyroxenes (I use the name generically) in the other slides. Further, the twinning is produced by narrow bands such as one obtains in the almost microlithic felspars of lavas, not in those of holocrystalline rocks such as picrites, gabbro, etc., and the outline of the grains is not that usual in felspars, but curiously irregular. Moreover, I find in a slide cut from the Carn Sparnack serpentine, both lamellar twinning and cross twinning in the less highly altered part of the pyroxenic constituent. I have measured the extinction angles of some of these compound grains, but to discuss the result would unduly extend this letter, so that I must content myself with affirming that these bear as much resemblance to the twinning of a plagioclase felspar as those noted by Mr. Teall, while they occur to such an extent that, if the mineral were felspar, the rock could not fail to give macroscopic indications of its presence. So, though I have endeavoured to approach the subject with the 'open mind' of some modern statesmen, I remain after repeated examination of the question of 'the same opinion still' that the mineral is not felspar. My suggestion as to its name was 'vague' designedly, for two reasons: (*a*) that it is very often easier to say what a mineral is not than what it is; (*b*) that I am by no means sure that these characteristics are exhibited by one mineral only; I believe it, however, to be always a member of the pyroxenic group, viz. some variety of augite, hornblende, or enstatite.

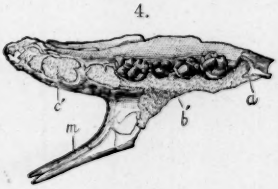
In conclusion, may I add that Mr. Teall appears to have slightly misunderstood the drift of my remark quoted by Colonel McMahon. Whether or not there is evidence of mechanical action on the serpentine at Porthalla is hardly germane to the question. Of course I should say that to assign the banded structure in this rock to pressure is at present just as much an hypothesis as it is in regard to the banded gabbro. But, apart from this, the difficulty, which I had felt and to which Colonel McMahon referred, was this—that, when the gabbro is so remarkably banded, then the serpentine shows little or no sign of mechanical disturbance. Porthalla is some miles from both Karakclews and the Landewednack district, and, so far as I know, gabbro does not occur in association with serpentine either there or near Mullion Cove.

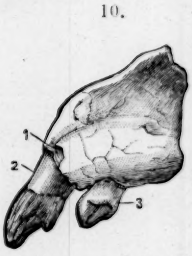
T. G. Bonney.



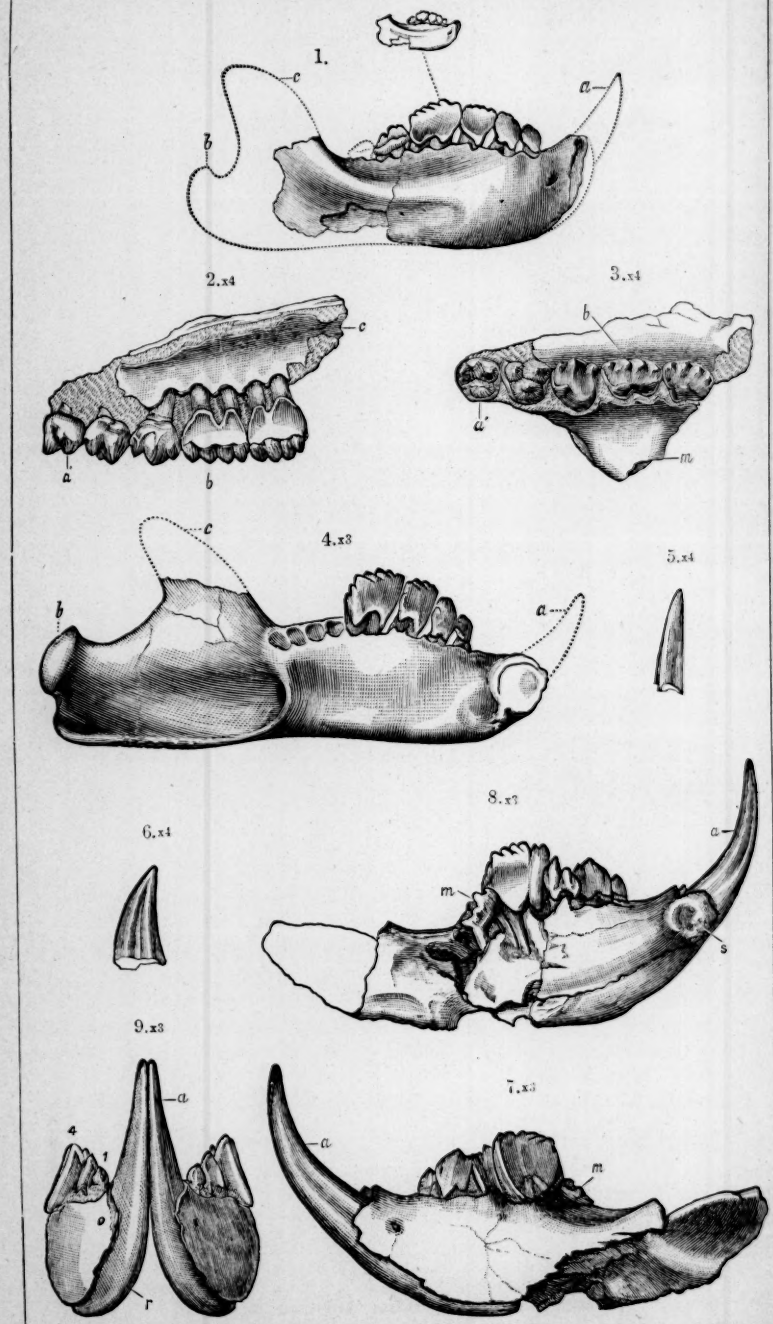








AMERICAN JURASSIC MAMMALS—ALLODON.



AMERICAN JURASSIC MAMMALS—CTENACODON.